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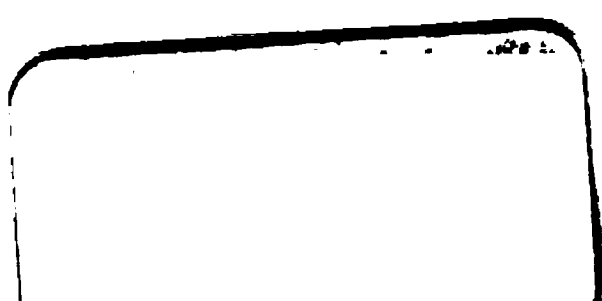
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THE
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CONDUCTED BY

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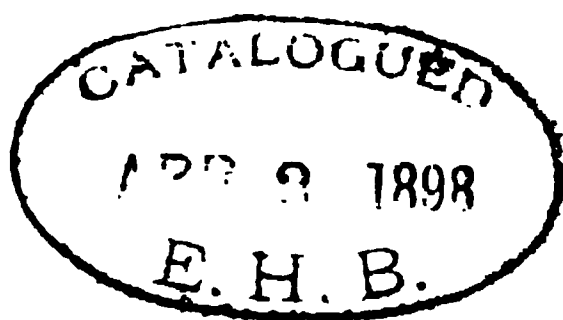
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Journal of Anatomy and Physiology.

THE TRINIL FEMUR (*PITHECANTHROPUS ERECTUS*),
 CONTRASTED WITH THE FEMORA OF VARIOUS SAVAGE AND
 CIVILISED RACES. By DAVID HEPBURN, M.D., F.R.S. Ed.,
Lecturer on Regional Anatomy, University of Edinburgh.

PROBABLY in recent times no keener incentive has been given to the study of the femur than by the discovery, at Trinil, in Java, of those remains which Dr Eugène Dubois, of the Netherlands East Indian Army Service, has rendered famous by the name of *Pithecanthropus erectus*. As described by Dr Dubois, these remains consisted of a skull-cap, two molar teeth, and a thigh-bone. From the various circumstances connected with their discovery, Dr Dubois claimed that the evidence was sufficient to prove that these different objects were parts of one animal; while, from the intrinsic features of each specimen, he asserted that they differed so markedly from the corresponding parts of man, on the one hand, and of the higher apes, on the other, as to necessitate the formation of a distinct genus for their inclusion, viz., *Pithecanthropus*, which approaches "nearest of all to Man, but cannot be included in the genus *Homo*."

It is needless to say that this theory has found both adherents and opponents. Among the latter, some maintain that the objects in question are undoubtedly human, others insist that they are as certainly the remains of a large ape. Still another group of critics regard the skull-cap as simian, and the femur as human; averring that the proofs of the remains belonging to one animal are insufficient and inconclusive.

For the purpose of bringing forward some additional information which may contribute to the solution of this much-debated problem, I have lately devoted special attention to the study of the femora in various modern races, both savage and civilised.

The femur has been selected for several reasons:—first, because in the Anatomical Museum of the University of Edinburgh there is a varied and instructive collection of the femora of many savage races, and by the kindness of Sir William Turner this collection has been generously placed at my disposal for examination; second, because a large body of skilled opinion has declared that the Trinil femur is human in form; third, because, although Dr Dubois has admitted that the femur “is human-like in all its essential features,”¹ yet he claims that it presents several differentiating characters which he has never found associated in any human femur; while, with regard to one of these characters which relates to the shape of the popliteal surface, he says he has never found it “in human femora, even separately.”

According to Dr Dubois, the chief differentiating features of the Trinil femur are the following:—

- (1) “the trochanteric line is less raised,”
- (2) “the shaft is, on the inner side, far more round,”
- (3) “the popliteal space is less developed, convex in its middle, so that at this height the shaft is almost round instead of flattened.”

It is to this character of the popliteal space which Dr Dubois could never find in human femora that I purpose directing special attention. Speaking of the small development of the popliteal space he says,² it “is in a high degree convex, because in the midst of it, and separated from the lips of the *linea aspera*, extends a kind of swelling until near the lower extremity, which is the reason that the lower part of the shaft of the femur has a round section. Again, in human thigh-bones the most backward projecting part of that space is in the neighbourhood of the outer lip of the *linea aspera*, whilst in the fossil Java femur this lip is situated much beneath (in a forward plane) from the most prominent part, this being in the middle.”

Since Dr Dubois contributed to the Royal Dublin Society the paper from which the foregoing quotation is taken, Professor Manouvrier of Paris has published an exhaustive criticism of

¹ Dr Dubois : *Trans. Roy. Soc. Dublin*, i., 1896.

² *Loc. cit.*

Pithecanthropus,¹ and in dealing with the femur he has shown that this feature of its popliteal surface is not unique, but that it has been seen by him in femora of the Guanche (Canary Islands), Venezuelan (pre-Colombian), Neolithic, and Ancient Peruvian races. In his elaborate memoir, Professor Manouvrier dwells upon the importance of having fixed points at which the transverse and antero-posterior diameters of the popliteal section of the femoral shaft should be measured. Both of these diameters are taken at the level of 4 cm. above the highest point of the anterior articular surface of the external condyle. In determining the antero-posterior measurement, the anterior end of the diameter should be taken from the most projecting part of the anterior surface of the shaft directly above the external condyle, and at the distance of 4 cm. from its articular surface, while the posterior end of the diameter should rest at a corresponding level,—first, upon the ridge which leads from *linea aspera* to the external condyle; and second, upon the middle of the popliteal space. The former of these antero-posterior diameters is symbolised by Professor Manouvrier as “mn,” and the latter as “mp.” In ascertaining the diameter “mn,” it is of great importance to avoid any confusion between the upward continuation of the ridge associated with the attachment of the outer head of the Gastrocnemius and Plantaris muscles, and the downward continuation of the external lip of the *linea aspera* or external pilastric prolongation. Further, Professor Manouvrier has shown that, when the diameter “mp” is less than the diameter “mn,” the popliteal surface is either flattened or more or less concave, but that when “mp” exceeds “mn” we find a popliteal surface more or less convex, and therefore one which is constructed on the same type as the popliteal surface of the Trinil femur.

In the measurements which I have conducted, I have adhered closely to the data laid down by Professor Manouvrier; and in calculating the popliteal *index*, I have invariably used the antero-posterior median diameter “mp.” I have also adhered rigidly to the system of taking the various popliteal diameters at the level of 4 cm. above the anterior border of the articular

¹ Manouvrier, “Deuxième étude sur le Pithecanthropus erectus, etc.” *Bull. de la Soc. d'Anthrop. de Paris*, Tome sixième, 1896, fasc. v. (iv^e serie).

surface of the external condyle, and have not availed myself of the latitude which Professor Manouvrier considers permissible, viz., to take a point somewhat higher or lower than 4 cm. according as the shaft of the femur is very long or very short.

Following out the methods indicated, I have examined and measured, with special reference to the popliteal region, the femora enumerated, viz., 13 Maori; 14 Aboriginal Australian; 12 Andamanese; 5 Sandwich Islands; 4 Lapp; 4 Eskimo; 6 Hindu; 2 Bengalee; 2 Sikh; 2 Malay; 2 Chinese; 2 Bushman; 2 Kaffir; 9 Negro; 2 Creole; 1 Egyptian; 3 Guanche; and several dozens of European and British femora obtained from the dissecting-room, and used for the ordinary purposes of anatomical teaching.

The majority of these race femora are in natural pairs, which is an interesting circumstance in relation to questions of variation; and I may mention that it is an extremely rare thing to find perfect symmetry between the two femora of the same individual in regard to corresponding measurements of any parts of the bones. My experience is that sometimes it is the left bone which exceeds the right bone in its chief features, and sometimes the right exceeds the left. The absolute number of femora included in the foregoing list is not very great, but they are spread over a large number of different races, and thus provide a wide and varied field of comparison with the Trinil femur.

So far as the foregoing list of femora has provided me with opportunities for observation, certain races, viz., Sandwich Islanders, Bengalee, Sikh, Malay, Chinese, Kaffir, Creole, and Egyptian, may be excluded from further consideration, at least in regard to the popliteal space, because in these races there was no evidence of convexity in that region. This fact may be expressed by saying that in the popliteal space of the femora of the races just named the antero-posterior diameter "mp" was always less than the antero-posterior diameter "mn," and in no instance did it therefore approach even in a slight degree to the Trinil type.

On the other hand, in certain races instances more or less numerous were found in which the Trinil feature of the popliteal space manifested itself with varying degrees of distinctness.

Consequently, in dealing with femora presenting more or less convex popliteal spaces, it is necessary to keep clearly in view the measurements of the popliteal section of the Trinil femur, which at the level of 4 cm. above the anterior superior border of the condylar articular surface measured:—

| | | |
|---------------------------------------|---|--------|
| Transverse popliteal diameter at 4 cm | . | 33 mm. |
| Antero-posterior „ „ („ mp ”) | . | 32 mm. |
| Trans. = 100, popliteal index | . | 96.9.* |

There can be no doubt that these are very remarkable figures, both as regards the diameters themselves and the high *index* they yield, an *index* only exceeded in two of the cases recorded by Professor Manouvrier. It must, however, be borne in mind that there are two factors to be considered in calculating an index, which merely expresses the relation existing between two diameters; and comparatively high indices may result from two entirely different conditions,—the one in which the transverse diameter is unusually small, the other in which the antero-posterior diameter is unusually large. High popliteal indices do not of necessity imply a convex surface in this region, and hence the importance of a comparison between the antero-posterior diameters “mp” and “mn.”

Now, although I have frequently found the diameter “mp” in excess of the diameter “mn,” yet 3 mm. is the maximum difference I am able to record between them. On the other hand, I have not found any instance of the diameter “mp” either equal to or greater than the transverse diameter, as was the case in the measurements from which the two highest popliteal indices recorded by Professor Manouvrier are calculated.

Of those femora which I have examined, the diameter “mp” was greater than the diameter “mn” in the following:—Lapp, 1; Eskimo, 1; Maori, 1; Hindu, 2; Negro, 3; Bushman, 2; Andaman, 5; Aboriginal Australian, 4; Guanche, 2; 4 European (British), (Table I.).

The various popliteal diameters and indices of these femora are tabulated in Table I., from which it will be seen that the increase of the diameter “mp” above the diameter “mn” fluctuated from 5 mm. to 3 mm., and is, moreover, of far less importance than the relative proportion of the diameter “mp”

* Quoted from Manouvrier's paper already referred to.

TABLE I.

Diameters of the Popliteal Region of the Femur at 4 c.m. above the anterior-superior articular surface of the External Condyle.

| | | | | | Transv. | Ant.-Post. | | Tr. = 100. |
|--------------------|---|---|---|------|---------|------------|------|------------------|
| | | | | | | mp. | mn. | Popliteal Index. |
| Lapp, | . | . | . | ♀ L. | 32 | 22·5 | 21·5 | 70 |
| Eskimo, | . | . | . | ♂ L. | 39 | 30 | 29 | 76·9 |
| Maori, | . | . | . | ♀ R. | 35 | 26·5 | 26 | 75·8 |
| Hindu, | . | . | . | ♂ R. | 37·5 | 31·5 | 31 | 84· |
| | | | | ♂ L. | 37 | 31·5 | 31 | 85 |
| Negro, | . | . | . | ♂ R. | 33·5 | 29 | 28 | 86·5 |
| | | | | L. | 34 | 28·5 | 28 | 83·8 |
| „ | . | . | . | ♂ R. | 36 | 32·5 | 32 | 90 |
| Bushman, | . | . | . | ♂ R. | 32 | 26 | 25 | 81 |
| | | | | L. | 32 | 26 | 25 | 81 |
| Andamanese, | . | . | . | ♂ R. | 27 | 24 | 23 | 88·8 |
| | | | | ♂ L. | 28 | 24 | 23 | 85·7 |
| „ | . | . | . | ♂ R. | 28 | 22 | 21 | 78·5 |
| | | | | ♂ L. | 29 | 21·5 | 21 | 74 |
| „ | . | . | . | ♂ L. | 29·5 | 24 | 23 | 81 |
| Aboriginal | . | . | . | ♂ R. | 34 | 31 | 30 | 91 |
| | | | | ♂ L. | 33 | 32 | 30 | 96·9 |
| Australian, | . | . | . | ♂ R. | 31 | 29 | 28 | 93·5 |
| „ | . | . | . | ♀ R. | 30 | 23 | 22 | 76·6 |
| Guanche | . | . | . | R. | 35 | 29 | 27 | 82·8 |
| | | | | L. | 37 | 29 | 27 | 78 |
| (Grand Canary), | . | . | . | | | | | |
| European | | | | | | | | |
| (British) „No. 2,” | . | . | . | ? L. | 45 | 38 | 35 | 84·4 |
| „ „ 4,” | . | . | . | ♂ L. | 35 | 31 | 30 | 88·5 |
| „ „ 5,” | . | . | . | ♂ L. | 44 | 34 | 32 | 77 |
| „ „ 6,” | . | . | . | ♀ L. | 35 | 31 | 30 | 88·5 |

to the transverse diameter, since it is by means of these two measurements that the *popliteal index* is calculated. Thus we may have a condition in which the diameter "mp" is greater than the diameter "mn," thereby indicating a tendency towards convexity of the popliteal space, and yet the *popliteal index* may be comparatively low, as in the Lapp femur and in the British femur "No. 5" (Table I.), because of the relatively large size of the transverse diameter. Similarly, in the British femur "No. 2" (Table II.) there is a pronounced increase of the diameter "mp" above that of "mn," viz., 3 mm.; and yet, when a high *popliteal index* might have been expected, it only comes to 84·4, by reason of the great width of the shaft in the transverse direction at the 4 cm. line, viz., 45 mm.

TABLE II.—Femur. (All measurements in millimetres.)
(Collection, Anatomical Museum, Edinburgh University.)

| Race. | Aboriginal Australian. | | | | Andaman. | | Negro. | | British, from Dissecting-room. | | |
|--|------------------------|--------|--------|--------|---------------|--------|---------|--------|--------------------------------|--------|--------|
| | S. H. N. S. W. | | Eucla. | | "Dr Dougall." | | Bengal. | | No. 4. | No. 1. | No. 2. |
| | L. | R. | L. | R. | L. | R. | L. | R. | L. | L. | L. |
| Age. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. |
| Sex. | ♀ | ♂ | ♂ | ♂ | ♂ | ♂ | ♂ | ♂ | ♂ | ♂ | ♀ |
| Total Oblique Length, | 361 | 455 | 461 | 455 | 361 | 382 | 478 | 496 | 436 | 415 | 397 |
| Diameter of head, | 39 | 45 | 44 | 45.5 | 38 | 38.5 | 47 | 45 | 47 | 41 | 48 |
| Subtrochanteric Region— | | | | | | | | | | | |
| Antero-posterior di., | 19 | 25 | 24 | 25 | 16 | 16 | 21 | 22 | 23 | 21 | 27 |
| Transverse di., | 28 | 30 | 31 | 31 | 23 | 22 | 28 | 29.5 | 33 | 35 | 26 |
| Platymetric index, | 67.8 | 83 | 77 | 80.6 | 73.7 | 72.7 | 75 | 74.5 | 65 | 60 | 115 |
| Diameters of middle portion of shaft. (Pistare)— | | | | | | | | | | | |
| (1) Transv. diam. at 4 cm., | 23 | 35 | 30 | 33 | 20 | 20 | 26 | 30.5 | 34 | 25 | 31 |
| (2) Max. bicondy. diam., | 22 | 31 | 26 | 26 | 20 | 20 | 22.5 | 24 | 26 | 24.5 | 27 |
| "100," | 104.5 | 112.9 | 115 | 126.9 | 100 | 100 | 115.5 | 127 | 130.7 | 102 | 114.8 |
| "mm," | 70 | 91 | 81 | 87.5 | 88.8 | 85.7 | 87.5 | 86.5 | 88.5 | 84.8 | 84.4 |
| "mp," | 32 | 34 | 31 | 32 | 27 | 28 | 32 | 33.5 | 35 | 33 | 45 |
| Distance from Ext. Condyle to Linea Aspera, | 64 | 78 | 76 | 82 | 71 | 71 | 80 | 74 | ... | 71.5 | 80 |
| | 50 | 43.5 | 40.7 | 39 | 38 | 39 | 40 | 45 | ... | 46 | 56 |
| | 21.5 | 30 | 28 | 31.5 | 23 | 23 | 29 | 28 | 30 | 28.5 | 36 |
| | 22.5 | 31 | 29 | 28 | 24 | 24 | 28 | 29 | 31 | 28 | 38 |
| | 81 | 95 | 118 | 105 | 105 | 107 | 120 | 112 | 75 | 104 | 98 |

The converse is equally true, *i.e.*, the diameter "mp" may be less than the diameter "mn," thereby indicating flatness or concavity of the popliteal space, and yet the *popliteal index* may be comparatively high, because of the relatively smaller dimensions of the transverse diameter. Thus a Bengalee femur gave the following diameters:—

| | | | | |
|-------------------------------------|---|---|------|--------|
| Transverse popliteal diameter | . | . | . | 32 mm. |
| Antero-posterior | " | " | "mp" | 28 mm. |
| " | " | " | "mn" | 29 mm. |
| Trans. diam. = 100, popliteal index | . | . | . | 87.5. |

A precisely similar index was also obtained from a Queensland femur (*v.* Table II.), in which the diameter "mn" was 3.5 mm. greater than "mp." Accordingly, I observe that as a general rule the highest popliteal indices are found in those femora which maintain to a low level the fairly uniform transverse proportions of the middle or pilastric section of the shaft. In other words, we may expect a high *popliteal index* if the transverse popliteal diameter (at 4 cm. above the articular surface of the anterior aspect of the external condyle) be less than 10 mm. in excess of the transverse diameter of the middle or pilastric portion of the shaft. In the Bengalee and Queensland femora above referred to, the increase in transverse diameter from the middle portion of the shaft downwards to the 4 cm. line was 6 mm. in the case of the former and 9.5 mm. in the latter. Of course, concurrent convexity of the popliteal surface would naturally still further increase the *index*. The femora presenting the highest *indices* given in Table I. all distinctly showed this feature of a very slight gradual increase in transverse dimensions from the middle of the shaft downwards, in addition to the convex condition of the popliteal space. Indeed, in the three male Australian femora whose popliteal *indices* were above ninety, the increase in transverse diameter from the middle of the shaft downwards to the 4 cm. line only varied from 1 to 5 mm.

It is for a similar reason that the Bengalee femur already referred to presented its comparatively high index without any trace of popliteal convexity. In Table II. detailed measurements of a number of femora are given for purposes of comparison.

Now, a slow or delayed rate of increase in the transverse diameters of the lower part of the femur—a condition which

may occur with or without any associated convexity of the popliteal space—tends to preserve the more or less cylindrical nature of the shaft, and in this connection it is interesting to note that one of the reasons which Professor Manouvrier assigns for the convexity of the popliteal space is the necessity for increased strength in an antero-posterior direction.

Another point of extreme interest brought out by my measurements of Australian femora is the fact that the "Swan Hill" femur, whose popliteal *index* is 96·9, not only exactly corresponds with the Trinil femur as regards this number, but also as regards the measurements from which this *index* is calculated. Further, the total oblique length of this Australian femur is 456 mm., while that of the Trinil femur is 455 mm. Again, both femora in question are from the left side of the body, and the right "Swan Hill" femur had a popliteal index of 91, with a total oblique length of 455 mm.

The next important feature which I have to note is, that of all the pairs of human femora which I have examined, only *two* pairs have yielded the same popliteal index for both bones, viz., a male Bushman and a female Eskimo. Throughout the whole of the remainder the greatest diversity exists. Sometimes the higher index lies with the left femur, sometimes with the right. Among Andamans, Australians, and Negroes I have noted as much as 6 points of difference between the popliteal indices of the right and left femora of the same individual; among Maoris and Sandwich Islanders, 4 points; in the Sikh, 3·9; in the Malay, 6·9; and between a pair of femora from a mound near Melita, Manitoba, as much as 7·6, in favour of the left bone. These facts seem to indicate that the conditions determining the popliteal index are the result of causes which rarely operate to an equal extent on both the bones of a pair of human femora.

From what has preceded, I think there can be no doubt that the occurrence of more or less of convexity of the popliteal space is sufficiently frequent to entitle it to rank as a human character, although it seems quite certain that this appearance cannot be regarded as a constant characteristic feature of any existing race. Moreover, its occurrence in varying degrees would seem to be restricted to a comparatively small number of modern races. Dr Dubois has referred to Manouvrier's cases as atavistic varie-

ties, and the same thing might be said of some of the instances in Table I., although, from the frequent occurrence of the condition among certain races, one would suppose that at least the Australian aborigines, Andamans, Bushmen, and some other tribes, are not far removed from the original possessors of the character, or that the causes producing this condition operate more frequently among these races. Indeed, one is forcibly reminded of the theory which, from the weapons, domestic implements, folk-lore, and rock-drawings, ascribed to these tribes a common ancestry on a continent now submerged in the Indian Ocean. At any rate, these races cannot be so far removed from the original possessors of the condition—(if such a race ever existed)—as those in which it has either not been observed, or only with great rarity.

So far, then, as modern savage and civilised races are concerned, their femora conclusively show that a more or less convex condition of the popliteal space in normal femora is not the exclusive possession of the Trinil femur.

The other two features of the Trinil femur, viz., concavity of the trochanteric line and convexity or roundness of the inner side of the middle portion of the shaft, are more easily dealt with, because they are not claimed as in themselves distinctive of the Trinil femur, but merely as important by reason of their association with the convex popliteal surface.

The two Chinese femora which I have examined present in a marked degree a convexity of the inner side of their shafts in the middle third; but apart from them, the Australian and Negro femora already referred to, without any doubt present all the three Trinil features conjoined on the same bones. As the two bones forming a pair are scarcely ever, if indeed ever, duplicated, it is not to be expected that any one bone will form an exact duplicate of the Trinil femur, but for all practical purposes of comparison the variations are not sufficiently great to constitute essential and distinctive differences.

Interpretation.

The interpretation of the meaning to be drawn from the occurrence of a greater or less degree of convexity of the popliteal surface of the femur is of importance for a variety of

reasons. We may take it as a general principle that the shaft of any long bone whose chief functions are associated with support and progression, owes its main proportions to the mechanical adaptation of its lines of resistance to the necessities of the attitude or gait adopted by the particular animal, and the details on its surface to the attachments, varying importance, and development of the different muscles concerned in maintaining and producing the attitude and gait. Thus we may have a close resemblance among long bones with regard to their general features, and a wide variety among them in points of detail, without transgressing the limits of normal anatomical variations. On the other hand, it is well known that all the foregoing conditions may be greatly modified by pathological changes, and in the present discussion these are fairly admissible, in view of the fact that the Trinil femur bore undoubted evidence of such pathological influences.

An increase in the amount of the antero-posterior popliteal diameter "mp" seems distinctly necessary for mechanical reasons, especially when we certainly find such an increase associated with a very small and gradual addition to the transverse diameters of the shaft from its middle portion downwards to the 4 cm. line.

The question of muscular attachments as an influence in increasing the convexity of the popliteal surface has been elaborately discussed by Professor Manouvrier in his memoir already referred to. He is of opinion that the muscles attached to the outer lip of the *linea aspera* may tend to preserve the cylindrical character of the femoral shaft to a lower level than usual when they maintain their vertical attachment on the posterior aspect of the shaft to a point below the level at which they usually diverge towards the external condyle, for in this way the length of the *linea aspera* would be increased, and the upper limit of the popliteal space correspondingly lowered. My measurements show that while the length of the popliteal space is undoubtedly diminished in many of the bones in which convexity of the popliteal surface is seen, yet such diminution does not occur in all the bones whose popliteal surface shows convexity; and when I have had a sufficient number of femora for comparison, I have found the shortest popliteal spaces in those

which presented no evidence of convexity in this region. When Dr Dubois exhibited and described his specimens in Edinburgh, I showed him several dissections of the lower limbs of the great anthropoid apes, and demonstrated various points in connection with the attachments of muscles to their femora. Thus, on the femur of the Gibbon (*Hylobates*), the vastus internus muscle is in close apposition with the femoral head of the biceps flexor cruris muscle at the upper end of the popliteal space, by reason of the insertion of the pubic portion of the adductor magnus muscle at a much higher level than is found in man, while the ischial portion of the same muscle is inserted not into the internal condyle of the femur, but into the middle of the internal supracondyloid ridge above and posterior to the level at which the femoral vessels pass backwards to become the popliteal vessels. Again, in the Chimpanzee, the insertion of the pubic portion of the adductor magnus extends downwards to be spread out on and "inserted into the greater part of the popliteal surface of the femur, extending as low down as the posterior ligament of the knee-joint."¹

In connection with this arrangement of muscles in the Chimpanzee and Gibbon, it is interesting to observe that in four Chimpanzee femora which I have measured, the diameter "mp" was greater than the diameter "mn" by 1 mm., while in two femora of a Gibbon (*Hy. syndactylus*) only one, namely the left, showed an increase of .3 mm. in favour of the diameter "mp." As the femora of the Gibbon were only approximately² 205 mm. in total oblique length, the 4 cm. line unduly favoured the antero-posterior diameters, for on measuring the same diameters at 2 cm. lower down, the diameter "mp" was less than the diameter "mn" in both femora. In the femora of the Gorilla and Orang-utan the diameter "mn" was greater than the diameter "mp."

Our knowledge of the muscular anatomy of the human popliteal space is derived almost entirely from the dissection of Europeans, in whom it is not usual to find the popliteal

¹ Hepburn : "The Comparative Anatomy of the Muscles and Nerves of the Superior and Inferior Extremities of the Anthropoid Apes," *Jour. of Anat. and Phys.*, vol. xxvi. p. 333.

² The skeleton was articulated.

surface of the femur clothed with muscle; but, as I have elsewhere pointed out (*loc cit.*), there is no difficulty in understanding the muscular channel by which the articular branch of the obturator nerve was carried to the posterior aspect of the knee-joint. It would be highly interesting to know the exact limits and dimensions of the femoral head of the Biceps flexor cruris and of the femoral insertion of the pubic portion of the Adductor magnus muscles, even among Europeans; and such an inquiry might readily be undertaken by the Collective Investigation Committee of the Anatomical Society.

Pathological Conditions.

Various explanations have been offered regarding the presence of the exostosis on the Trinil femur. Into a discussion of these I need not enter, since it is sufficient for my purpose that the Trinil femur is not absolutely normal, and examination of other pathological specimens is therefore permissible.

It is quite clear that an inflammatory condition such as periostitis may tend to fill up hollows on bones as well as to accentuate existing elevations or convexities; moreover, in the case of a slender bone presenting a rachitic tendency to antero-posterior curvature, one might naturally expect additional ossific activity in the neighbourhood of an epiphysial cartilage by way of mechanically counteracting such rachitic tendency. On the other hand, any pathological condition of long standing must necessarily have interfered with the physical activity of the individual, and thereby both the muscular development and the curves normal to a femur must have suffered serious modification. None of the femora already referred to as possessing a popliteal surface more or less convex, present any evidence of inflammatory thickening so far as the popliteal surface is concerned, although a certain amount of the convexity of the inner side of the middle portion of the shaft may have been produced by periostitis in the "Swan Hill" femora.

In the Pathological Collection of the University of Edinburgh there is a rachitic femur (526) which has the following measurements:—

| | |
|---|---------|
| Total oblique length, | 365 mm. |
| Diameter of head—(head damaged). | |
| Subtrochanteric diams. :— | |
| (a) Antero-posterior, | 23 |
| (b) Transverse, | 27 |
| <i>PlatymERIC index</i> , | 85 |
| Diams. of middle region of shaft :— | |
| (a) Antero-posterior, | 26 |
| (b) Transverse | 26 |
| <i>Pilastric index</i> , | 100 |
| <i>Popliteal index</i> , | 96·8 |
| (i) Popliteal width at 4 cm., | 32 |
| (u) Max. bicond. width, | 73 |
| $u = 100.$ $i =$ | 43 |
| Distance of linea aspera from external condyle, | 85 |
| Diam. "mn" | 27 |
| „ "mp" | 31 |

This femur had a pronounced antero-posterior curvature of the shaft, but did not present evidences of inflammatory thickening except in the popliteal space, where the surface between the two supracondyloid ridges was uniformly raised and occupied by bone of a slightly more porous texture than the surrounding parts. I have introduced reference to this femur because it affords an illustration of localised thickening affecting an important diameter, and thereby raising the *popliteal index* to a very high figure in an artificial way. It seems difficult to suggest an explanation of this local increase, unless it be that the deposition of new material provided a kind of buttress for resisting the antero-posterior bending. I have seen another instance of this localised popliteal thickening, although to a less extent than in the rachitic bone, in a femur taken from the general collection of femora used for ordinary teaching purposes. This specimen is included as No. 1 at the end of Table II. The shaft was rather straighter than usual, and there was no evidence of inflammatory thickening, except in the popliteal space. By far the most remarkable feature of this bone was its *PlatymERIC index*, which was almost as low as that of the lowest Maori indices. It is not quite certain, of course, to what

nationality this femur really belonged, but there was no possibility of its belonging to a Maori, since it must have been prepared many years ago from an ordinary dissecting-room subject. The measurements show a close approximation of "mp" to "mn"; and had the individual lived some years longer, the relation between these diameters might have been more pronounced. As it is, even although "mp" is less than "mn," the *popliteal index* is fairly high, because of the slender nature of the shaft, and its very slight increase in transverse diameters from the middle of the shaft downwards to the 4 cm. line.

Conclusions.

I. Convexity of the popliteal surface of the femur is not a feature exclusively seen in the Trinil femur, but is found in a proportion of the femora of existing races, in varying degrees, even up to the same amount as in the Trinil femur, as shown by the *popliteal index*.

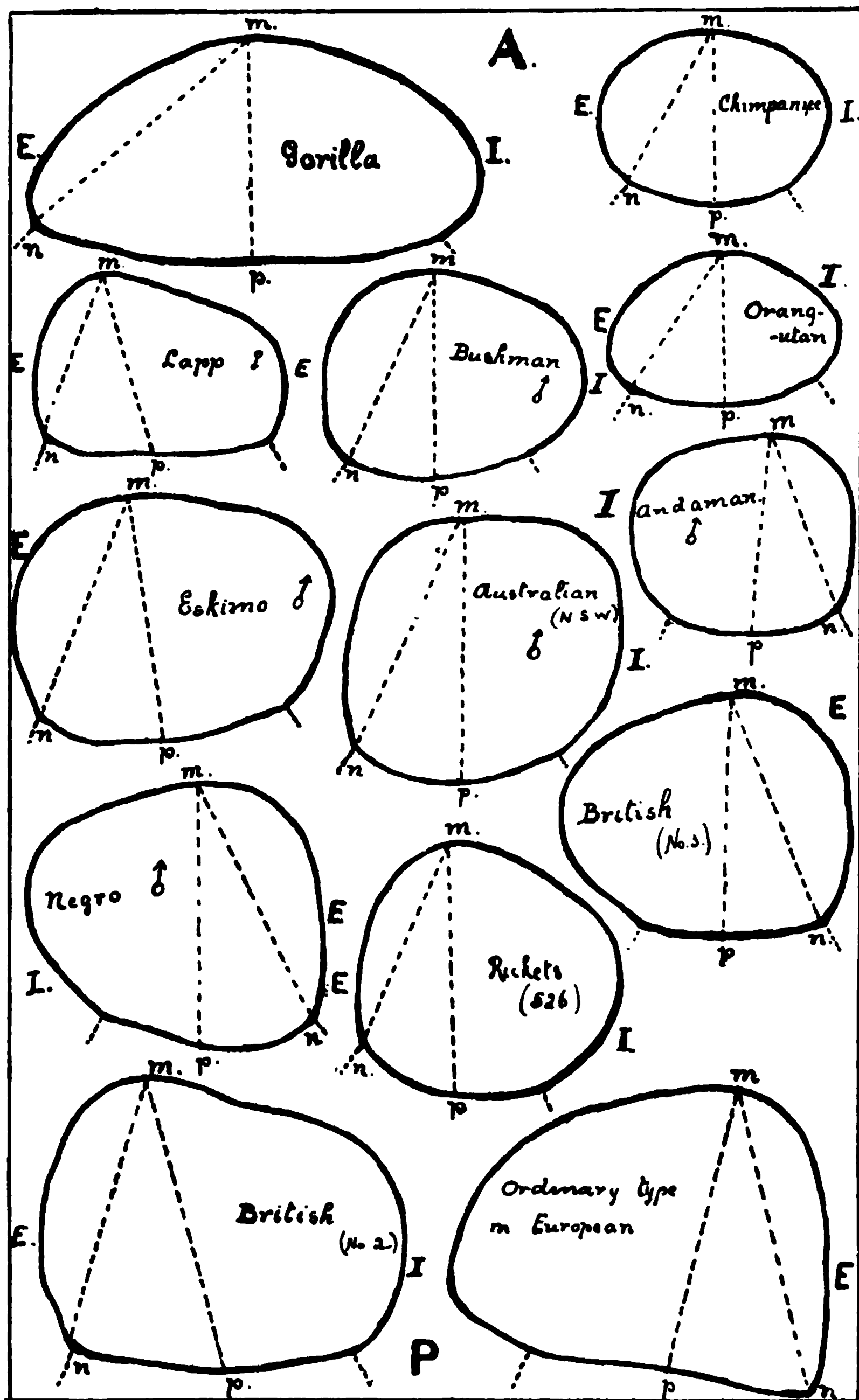
II. Concavity of the anterior intertrochanteric line, together with convexity of the inner surface of the middle portion of the femoral shaft, is to be found on human femora, not only singly, but also associated with convexity of the popliteal surface.

III. The frequency with which these features are found on human femora entitles them to rank as human characteristics.

IV. The femur of Trinil has not been shown to possess features entitling it to the distinction of a separate genus, but is a human femur, which from the geological horizon connected with its discovery associates the genus *Homo* with a period more remote than any former discovery of man's remains.

V. Laying aside the foregoing characters of the Trinil femur the appearances of its condyles, their articular surfaces, and the intercondylar notch are peculiarly human, and not simian.

VI. Reasoning from these conclusions, with regard to the femur, either the skull-cap and the molar teeth were also parts of a human being, or it has yet to be proved that they really formed parts of the individual who provided the femur.



EXPLANATION OF THE FIGURES.

These outline figures represent transverse sections of the popliteal region of various femora at the level of the 4 cm. line. They were made with thin strips of flat lead, and are reproduced in natural size. The letters correspond throughout:—A, anterior; P, posterior; E, external; I, internal; “mn” and “mp” are the two antero-posterior diameters referred to in the text.

Table II. contains the detailed measurements of the Lapp, Andaman, Australian (Swan Hill, N.S.W.), Negro (articulated skeleton), and British (No. 2) femora, of which outline sections are given.

Table I. contains the popliteal diameters of the *figures* representing sections of the femora of an Eskimo and a Bushman.

The details of the Rachitic femur (526) are included in the text.

In the British femora “No. 3” and “ordinary type” the diameter “mp” was less than the diameter “mn,” but in the former bone the *popliteal index* was higher than the latter, by reason of the pronounced difference in the proportion of their transverse diameters.

In the Gorilla and Orang-utan “mp” was less than “mn,” while in the Chimpanzee “mp” was greater than “mn.”

Right femora are represented by the Andaman, Negro, British (No. 3), and ordinary European type; all the other figures are from *left* femora.

The *dotted lines* outside of each figure indicate the lateral ridges which limit the popliteal space.

A PRELIMINARY NOTE ON THE DEVELOPMENT OF
THE CLITORIS, VAGINA, AND HYMEN.¹ By D.
BERRY HART, M.D., F.R.C.P.E., *Lecturer on Midwifery and
Diseases of Women, School of Medicine of the Royal Col-
leges (Surgeons' Hall), Edinburgh.* (PLATES I.-VI.)

WHILE much has been done to put the development of the female genital organs on a satisfactory basis, there are certain points in which our knowledge is defective, as well as some outstanding facts which have not yet received a clear explanation, and can thus only be classed as anomalous. In the first place, so far as our present knowledge goes, it is remarkable that in the foetus at full time a hymen is always present; and still more remarkable that even in atresia vaginæ the hymen, and occasionally a double hymen, is developed. Why should the hymen be always present in the full-time foetus? Why in atresia vaginæ should the hymen escape the atresia?

Then, again, the structure of the vaginal mucous membrane is quite analogous to that of skin. We have many layers of a squamous and quite characteristic nature, the cells of the deeper layers being more oval and staining more deeply. The superficial layers desquamate like skin; there are practically no glands present, and in prolapsus uteri the everted mucous membrane takes on the appearance of the body skin. One would expect, therefore, an epiblastic origin for the lining of the vagina and the outer covering of the vaginal cervix. The genital tract is stated to be developed, however, from the ducts of Müller, the non-coalescing parts forming the Fallopian tubes, the coalescing portions the uterus and vagina. The ducts of Müller arise probably from the mesoblast, the Wolffian ducts from the epiblast. The received opinion is, therefore, that the vaginal lining is derived from Müller's ducts, a mesoblastic source, and that the Wolffian ducts and bodies have only an important excretory function in the early foetus until the permanent kidneys develop. Their importance, as active organs, then ceases, and

¹ From the Laboratory of the Royal College of Physicians, Edinburgh.

they are considered as possessing merely a pathological significance, as they provide the gynecologist with the well-known parovarian cyst, with some of the papillomatous tumours of the ovary and broad ligament, as well as some of the rarer vaginal and broad ligament cysts. Some observers assert that the Wolffian ducts enter into the formation of the lower part of the vagina; and Pozzi, in a very acute and able manner, gives most excellent reasons for considering the hymen as not vaginal. Whether he is right in stating that it is to be considered vulvar, remains to be seen.

For some time past I have had prepared for microscopica



FIG. 1.—Vertical mesial section of the female pelvis (modified from Foster). A cross marks the site of the hymen, and the lining of the vagina derived from the Wolffian bulbs has a dotted outline.

examination the pelves of early fetuses, male and female, the paraffin method being employed and the material cut serially. I examined them at first for my own information and for teaching purposes, but the remarkable developmental changes roused my interest, and induced me to go more thoroughly into the matter than I had at first intended. From the published works and papers of His, Waldeyer, Dohrn, Nagel, v. Mihalkovics, Budin, Tourneux and Legay, Klein, Pozzi, Kollmann, Keibel, and from the suggestive text-book of Minot, I received much valuable information, but no answer to the initial difficulties I have

stated. A prolonged and careful examination of my specimens seems to me to have cleared up these anomalous points, and this is my reason for publishing the present communication, and committing what the professed embryologist may consider a trespass.

The question to be considered will be clearly understood if figs. 1 and 2 be first studied. Fig. 1 (text) shows a vertical mesial section of an adult pelvis. One sees the hymen on section, and the vagina with its outline dotted where its lining is derived, from the Wolffian ducts, as I hope to show, and therefore epiblastic.

Farre and Cullingworth accurately describe the hymen as a pouting vertical slit, and there is no doubt that some of its various shapes are made by the method of examination.

FIG. 2.—From Keibel's model of organs in foetus at about eighth week. The eminence of Müller, where the hymen will develop, is marked with a cross, which also lies at the upper end of the sinus. (8.)

Fig. 2 (text) shows Keibel's valuable model of the relations at the eighth week; it is practically the same as in the seven weeks' foetus, of which sections are given in the Plates. It is at Müller's eminence that the hymen is developed, and the main object of this note is to determine some of the changes transforming fig. 2 into fig. 1.

The specimens I had for examination were as follows:—(1.) Serial sections of a five weeks' foetus, carefully prepared and stained, which I owe to the kindness of Dr H. J. Stiles. (2.) A seven weeks' foetus, also serially cut. This was from a cancerous seven weeks' pregnant uterus, successfully extirpated by me, and prepared and stained by Dr Lovell Gulland. (3.) A foetus at

the third month, perfectly fresh and well preserved. (4.) A four and a half months' foetus; and (5.) one at full time. I also examined several male pelves as well as those of foetal rabbits, but do not consider these at present.

The foetuses (3.) to (5.) were prepared by Mr Hume Patterson at the Laboratory of the Royal College of Physicians, where also the microphotographs and transparencies were made. I am greatly indebted to Mr Patterson for the skill he displayed in the preparation of the specimens and photographs.

The early foetuses were cut serially and transversely by the paraffin method; all the sections were mounted. The later foetuses were treated in the same way, but only every sixth could be mounted, and the sections were cut in the sagittal mesial plane. Mr Stiles' preparation had been stained in carmine in block; for all the rest, logwood and eosin were employed.

Based on this examination, and on the literature of the subject, I shall now consider—

(1.) *The development of the genital tract prior to the formation of the hymen.* This is well illustrated by the foetuses of the sixth and seventh week.

(2.) *The origin and development (a) of the prepuce of the clitoris, and (b) of the hymen.* The foetuses of the third and fourth month illustrate this stage.

(1.) *The development of the genital tract prior to the formation of the hymen.*

In the seven weeks' foetus one finds, in the abdominal cavity, the peritoneal ridges, one on each side of the middle line, with the Wolffian bodies. Lower down, the outer ridges with the Wolffian and Müllerian ducts appear; and at the lower levels, the ovary with its characteristic pedunculated form comes into view, lying on what will be the posterior lamina of the future broad ligament. The Wolffian bodies have greatly lessened in size, and at the level of the ovary are much diminished in section. The outer ridge is hour-glass shaped on transverse section. In the outer segment the ducts of Wolff and Müller develop: the inner one becomes the ovary. The outer joins its fellow to form the broad ligament in front of the ovarian part, which thus comes to lie behind.

In the broad ligament we have the Wolffian ducts and ducts of Müller, and at a lower level the genital cord of Thiersch. In the five weeks' foetus we find four canals in the genital cord, the two outer being the Wolffian ducts, the two inner the ducts of Müller. In the six weeks' foetus the ducts of Müller have coalesced into one canal, but the Wolffian ducts are distinct. Still lower we get the Wolffian ducts opening into the urino-genital sinus, while the ducts of Müller end in the eminence of Müller between these (*v.* Pl. I.).

Immediately before the Wolffian ducts so end they flatten out laterally, and with the Müllerian ducts form an H-shaped appearance on transverse section (Pl. III. fig. 6). So far, then, it is certain that the Anlage of the greater part of the vagina is the ducts of Müller, with probably a part of the Wolffian ducts where the adult vagina is H-shaped on transverse section. (Hoffmann, quoted by Pozzi; but I have not been able to get the original paper.)

(2.) *The origin of (a) the prepuce of the clitoris and of (b) the hymen.*

In the four and a half months' foetus the coronal section of the glans clitoridis shows a remarkable horse-shoe like structure surrounding the glans tissue. The margins of the horse-shoe consist of a layer of active cells staining deeply, while between these we have less deeply stained cells (Pl. IV., figs. 7 and 8). So far as one can determine, they are epithelial cells. Their origin and nature are clearly determined in the sagittal sections of the glans in the three and a half months' foetus, where one sees, at the lower part of the clitoris apex, the epidermis sending in two sickle-shaped processes whose apices do not meet (Pl. IV., fig. 7). This is really a thimble-like involution of epidermis, the open base of the thimble being at the corona. The superficial layers of the epidermis are necessarily in the centre of these involutions. The clitoris in the early foetus is bulbous and entire (Pl. V. fig. 10). The involution, as already described, takes place at or about the third month, and the separability of the prepuce is formed by the central cells, which are really the superficial ones, desquamating; *i.e.*, the prepuce is now the movable hood we find in the adult.

To see the changes which bring about (b) *the development of the hymen*, we must examine sections at the third and fourth month respectively.

The specimens I examined were at the third and a half and fourth month, and the sections were cut sagittally in the former specimen, and in the axial transverse direction in the latter; *i.e.*, from side to side, and in the axis of the brim in the four and a half months' one.

Remarkable changes have taken place in the vagina. We have seen that in the early foetus the vagina was formed from the coalesced ducts of Müller, and that a lumen was present, the cavity being lined with a single layer of cells. What we now find is as follows:—At what we may term the site of the vaginal entrance one sees an ingrowth, the deeper layer of the vestibule lining passing in, and with it the superficial layers too. This passing in of the superficial layer is, as in the case of the clitoric prepuce, of great importance, as it is the desquamation of these superficial layers, however effected, that gives rise to a lumen. The passage is in the form of multiple tubular ingrowths, so that we see on section several canals the walls of which gradually disappear and thus a single canal up to the outer aspect of the hymen is formed (Pl. IV. fig. 7).

A little higher in the vaginal axis remarkable structures are now to be noted, *viz.*, two oval collections of cells from which cords of actively proliferating cells pass in several streams, as it were, to fill up the vaginal lumen as far as the cervix uteri, where in this specimen the posterior fornix is mapped out by a sickle-shaped prolongation of the cells. The vaginal lumen is solid below, but higher up a lumen has begun to form. The periphery of the bulbous collection of cells is mapped off by actively growing cells, while the mass of the bulb is made up of epithelial cells exactly similar to those of the epithelial lining of the fully developed vagina, the peripheric cells being the same as those in the deeper layers of the vaginal epithelium. In regard to this bulb an examination of all the sections shows that the following conditions are present: At a little distance from the middle line it is solid; in the middle line it has a lumen in the form of a vertical slit; while further out a second bulb is seen and with a duct, the Wolffian duct passing into it. One of

the bulbs is the larger, and they lie laterally in relation to one another (Pl. VI. fig. 12; and Pl. II. figs. 3 and 4).

I may anticipate here, for convenience of terminology, one of the chief conclusions of my paper, by saying that these bulbs are Wolffian in their origin—*i.e.*, are derived from the Wolffian duct—and I shall now term them the Wolffian bulbs.

It is evident that we can now explain the hymeneal opening of the vagina, as we must distinguish between this and the formation of the fully developed hymen and its varieties. At present I only consider the former question.

The hymeneal opening is evidently formed by a vestibular involution from below meeting the bulbar distensions above, and causing a thinning, and ultimately a perforation, of the intervening tissue.

The four and a half months' pelvis shows the fully-formed and coalesced bulbs with a vertical slit, and according to the obliquity of the section we get either one bulb or both. Between the lower ends of the bulb is a vertical spur, the rudiment of the posterior vaginal column (Plate V. fig. 9).

The full statement of the formation of the vagina and hymeneal opening seems to me to be as follows:—Up till the origin of the hymen the vagina is Müllerian and lacking its lower end. Then comes the formation of the Wolffian bulbs by a proliferation of the lower ends of the Wolffian ducts. The epithelium of these ducts, epiblastic in their origin, forms the Wolffian bulbs, and, proliferating, passes up into the vaginal canal, filling up its lumen, mapping out the fornices, covering the vaginal portion of the cervix, and passing at first into the lower part of the cervical canal. The central cells are the least active and become shed; that is, a lumen is formed. The vaginal entrance is formed where the epiblastic ingrowth from below meets the bulbar distension above, and this is the developmental definition of the hymen and the vaginal entrance.

The view, so ably advocated by some authors, that the fully-formed vaginal lining is derived from the ducts of Müller, is full of difficulties. It would make the vaginal lining mesoblastic, and give no explanation of the remarkable blocking of the vagina with cells while the hymen is being formed, as well as no reason for the different lining of the adult vagina, uterus, and tubes.

The lining of the uterus is Müllerian and mesoblastic, that of the vagina is Wolffian and epiblastic.

The question of the relation of these ducts to the germ layers is, however, much disputed. In the Elasmobranchs they appear to have a common origin. So far as my reading and examination of specimens go, I am of opinion that the Müllerian duct is mesoblastic in the human foetus, but that at its very lowest part the vagina is Wolffian, and therefore epiblastic, and that as the hymen is derived from the Wolffian bulbs, its inner surface is epiblastic. Its outer surface is really hypoblastic, being derived from the lining of the urino-genital sinus.

The view I advance seems to me to explain the development so far as the points stated in the beginning of the paper are concerned, and may be summed up as follows:—

1. Before the hymen is developed—*i.e.*, up till the second and third month of foetal life—the vagina is formed by the coalesced ducts of Müller, but no lower aperture and no hymen are present; the vagina is Müllerian and blind.

2. At the beginning of the third month two bulbs form from the lower ends of the Wolffian ducts, the periphery of these bulbs being formed from the more active cells, the central of cells of a more squamous type. The cells are, in fact, the same as those of the adult vagina.

3. By the proliferation and spread of these cells the Müllerian vagina has its lumen blocked, the fornices and vaginal portion of the cervix mapped out.

4. The Wolffian bulbs coalesce, break down in the centre, and as the Wolffian cells in the centre of the Müllerian vagina do the same, we get the normal vaginal lumen formed.

5. The hymeneal opening is brought about by the epithelial involution from below meeting the distending bulbs above.

6. The ducts of Müller determine the site of the vagina; the Wolffian ducts supply its lining and develop the hymen (*v.* also 5).

The bearing of these views on Atresia vaginæ is as follows:—

1. Atresia vaginæ is atresia of the Müllerian vagina, but the hymen, being Wolffian in origin, is present.

2. The reason a hymen is always present in the fully-formed foetus is as follows:—The Wolffian bulbs form the hymen and

obliterate the lower ends of the ducts of the Wolffian bodies, and as these are the temporary kidneys of the foetus, they must of necessity have been present during the early life of a fully developed foetus.

3. The double hymen is not due to a permanent duplicity of the ducts of Müller, but to a non-coalescence of the Wolffian bulbs. The vertical slit of the hymen is due to the apposition of the latter Wolffian bulbs.

4. In imperforate hymen the tissue between the involution from below and the Wolffian bulbs has not been perforated.

The real essence of all this development seems to be as follows:—In the fully-formed genital tract we have the lining of the uterus developed from the ducts of Müller, and having as its great function pregnancy and menstruation. Its single epithelial layer and delicate connective tissue fit it for these functions; but for the pressure of parturition which the vagina has to undergo, we need a multiple, squamous, in fact, skin-like structure, such as is supplied from an epidermic source. One can see the great difference in the mucous membranes of, say, an inverted uterus and prolapsus uteri. In the one we have a raw, bleeding surface, quite unfitted for friction; in the other a structure that soon becomes skin-like and horny. To give the vagina this skin-like structure we get the Müllerian lining replaced from the epiblastic Wolffian bulbs; these at the same time taking a part in the formation of the hymen, as already described.

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See Tourneux and Legay, and Hertwig's text-book for full literature.

DESCRIPTION OF PLATES I-VI

Pl. I, fig. 1.—T. S. of seven weeks' foetus. *a* is in Wolffian duct; *c* points to summit of bladder. ($\frac{2}{1}$.)

Fig. 2.—T. S. at level where broad ligaments have formed. *a* is ovary; *c* points to Wolffian relics; *d* is Wolffian duct; *e*, duct of Müller. In both figures the spinal cord lies behind. ($\frac{2}{1}$.)

Pl. II, fig. 3.—Shows Wolffian bulbs. The larger one shows the epithelium proliferating into the Müllerian vagina; at the side is seen the second Wolffian bulb at its outer aspect, with the Wolffian duct passing into it. Wolffian duct has *b* in its lumen; *a* is larger Wolffian bulb. ($\frac{2}{1}$.)

Fig. 4.—Wolffian duct and Müllerian vagina. Müllerian vagina, *a*: Wolffian duct, *b*. ($\frac{2}{1}$.)

Pl. III., fig. 5.—T. S. showing genital cord. *a* points to the three canals in it; the central one is the coalesced Müllerian ducts; the outer are the Wolffian ducts. *b* points to the eminence of Müller in the urino-genital sinus. It is at the eminence of Müller that the hymen forms. ($\frac{2}{1}$.)

Fig. 6.—T. S. shows genital cord as in fig. 5. In the urino-genital sinus the openings of the Wolffian ducts can be seen; *a* points to genital cord; *b* to urino-genital sinus. ($\frac{2}{1}$.)

Pl. IV., fig. 7.—Sagittal mesial section of pelvis of three and a half

months' female foetus, showing development of hymen and formation of prepuce of clitoris. *e* is epidermis passing to map out glans; *a* is on Wolffian bulb, which is breaking down centrally; and *b* is involution from urino-genital sinus to meet distending Wolffian bulbs and make hymeneal opening. ($\frac{8}{1}$.)

Fig. 8.—Coronal section of four and a half months' foetus to show passing of epidermis to form prepuce. *b*, glans clitoridis; *a* points to active layer of epidermis. ($\frac{8}{1}$.)

Pl. V., fig. 9.—Coronal section of pubic arch of four and a half months' foetus between the layers of triangular ligament. *a* is lower end of urino-genital sinus; *c* is at upper end; *b* is the lateral half of the hymen developed from one of the Wolffian bulbs; the section has missed the other half, but one can see the spur representing the posterior column of the vagina; *d* is on Bartholinian gland. ($\frac{8}{1}$.)

Fig. 10.—T. S. six weeks' foetus (Stiles), shows early clitoris and urino-genital sinus, *a*, *b*. ($\frac{8}{1}$.)

Pl. VI., fig. 11.—T. S. seven weeks' foetus showing cloaca. Rectum, *b*; urino-genital sinus, *a*. ($\frac{8}{1}$.)

Fig. 12.—Vertical mesial section of three and a half months' foetus. Wolffian bulbs, *a b*; *c* is Müllerian vagina, with epithelial proliferation in it, and posterior fornix mapped out. Rectum, *d*; symphysis, *e*. ($\frac{8}{1}$.)

**A NOTE UPON THE VIBRATIONAL RATE OF THE
MEMBRANES OF RECORDING TAMBOURS. By
DAVID FRASER HARRIS, B.Sc. (Lond.), M.B., C.M., F.R.S.E**

(From the Physiological Laboratory, University of Glasgow.)

SEEING that certain observers believe that the inertia of the lever and india-rubber covering of recording tambours (*e.g.*, Marey's) is a source of error in tracings with these instruments, and seeing that these tambours have been widely used for graphic representations of movements of very different vibrational rates, I thought it well to attempt to estimate the period of oscillation of lever and membrane after mechanical agitation. I took an ordinary Marey's circular recording tambour (4.5 cm. diam.) covered with thin sheet india-rubber, stretched to medium extent, and carrying a light straw lever, 12 cm. in length, furnished with the usual short quill writing-style. The tambour was mounted on a heavy brass stand, and its quill touched the smoked paper of a drum rotating at the rate of 14 cm. per 5". The drum having attained full speed, I struck the table (a large, heavy one, screwed to the floor) with a violent blow of the clenched fist, in order to set up free oscillations of lever and india-rubber, according to their own proper period dependent on their inertia. Only the amplitude of the oscillations, not their rate, was altered with varying degrees of energy of blow. The blows were given at intervals, on an average, of .5", the amplitude of the initial excursion of the lever varying from 4 mm. to 1.5 mm. according to the violence of the blow.

The period or vibrational-rate appeared by this method to be, on an average, 56 per 1"; the tracings showing 10 vibrations per 5 mm. of paper with striking uniformity in a large number of trials.

[Speed was 14 cm. per 5"

\therefore per 1" $\frac{14}{5}$ cm. ;

now in 5 mm. there were 10 oscillations

\therefore in 1 cm. 20 "

$$\therefore \text{ in } \frac{14}{5} \text{ cm.} \quad . \quad . \quad \frac{20 \times 14}{5} \text{ oscillations,}$$

or 56 per second.]

The oscillation usually gave a visible tracing for only .25", the amplitude rapidly dying away after 3 or 4 oscillations. In other words, the inertia of the india-rubber membrane of a 4.5 cm. diam. Marey's tambour expresses itself in an oscillation having a rate of between 50 and 60 per second, being in this case elicited by mechanical agitation of considerable energy.

I venture to think, therefore, that this alleged source of mechanical error can constitute an element of fallacy only in tracings of such movements as have a period somewhere between 50 and 60 per second.

Provided that a time-tracing be simultaneously taken, the rate of the main series and of superimposed wavelets could always be estimated. Without doubt each tambour has a different period from every other, dependent upon the extent, the thickness, and the tension of its membrane, and upon the weight and length of its lever.

Thus, in any investigation making use of such instruments, and especially when, in interpreting the curves, stress will be laid upon any small waves (rapid vibrations), or upon small waves superimposed upon larger (slower) ones, it would be necessary to determine, in some such fashion as the above, the "proper period" of the apparatus. According to my observations, the instrumental oscillations, even when set up by considerable violence, tend to cease (or become so small as to give no tracing) in the comparatively short time of .25". Professor Haycraft seems to have elicited vibrations of a cardiograph by surprisingly gentle pressures—light taps of the finger upon the membrane. From the above observations I would scarcely have expected such slight agitation to have set up the "proper period" oscillations described by Haycraft with such care.¹ The upper tracing he gives on p. 457 closely resembles several I obtained, and had it happened to be accompanied by a simultaneous time-tracing this note would be superfluous.

¹ "The Movements of the Heart within the Chest and the Cardiogram," *Jour. of Physiol.*, vol. xii., 1891.

**SIXTH ANNUAL REPORT OF THE COMMITTEE OF
COLLECTIVE INVESTIGATION OF THE ANATOMI-
CAL SOCIETY OF GREAT BRITAIN AND IRELAND,
1895-96.¹ Reported by F. G. PARSONS and ARTHUR
KEITH.**

THE following questions were issued by the Committee of Col-
lective Investigation in January 1895:—

1. The eighth costal cartilage:

(a) The distance in millimetres at which its extremity is
placed from the margin of the sternum.

(b) The condition of the first lumbar vertebra in regard
to its rib-element in those cases in which the eighth
costal cartilage articulates with the sternum.

(N.B.—The side on which the observation is
made and the sex of the subject to be in every case
indicated.)

2. The relation of the great sciatic nerve to the piriformis
muscle.

3. The mode of termination of the internal plantar artery.

4. The arrangement and number (if possible) of the lymphatic
glands accompanying the common, external, and internal iliac
arteries.

5. The mode of origin of the branches of the internal iliac
artery.

The Sixth Annual Report shows a marked falling off in the
number of observations from those that have preceded it. The
Committee is disposed, however, to look upon this as due, not so
much to indifference on the part of observers, as to the fact that
the questions were not sent out until after the middle of the
winter session of 1894-95. In spite of the small amount of
statistics, it has been thought advisable to publish a report as
usual, in order that the custom should not fall into abeyance;
but it should be borne in mind by any one inclined to criticise

¹ The Fifth Report will be found on p. 35 of the *Journal of Anatomy*, vol. xxix.

this report, that its deductions are derived from an admittedly small amount of material, and are not intended to be final.

QUESTION I.

The eighth costal cartilage :

- (a) The distance in millimetres at which its extremity is placed from the margin of the sternum.
- (b) The condition of the first lumbar vertebra in regard to its rib-element in those cases in which the eighth costal cartilage articulates with the sternum.

(*N.B.*—The side on which the observation is made and the sex of the subject to be in every case indicated.)

Reports on this question have been received from the following gentlemen :—

A. Low, Aberdeen University ; G. Farmer, Oxford University ; A. Keith, London Hospital ; M. Cameron, London Hospital ; R. W. C. Pierce and H. E. Hewitt, St Thomas's Hospital.

Altogether reports have been received of 63 adult males, 31 adult females, and 12 children.

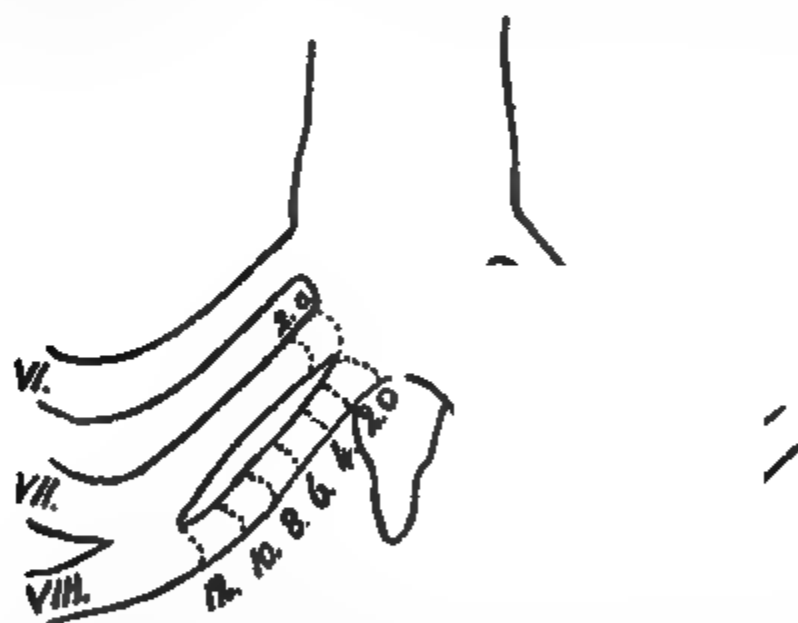


FIG. 1.

The Committee desires to express its indebtedness to Mr M. Cameron for his valuable series of statistics from the post-mortem room of the London Hospital, and to hope that, in future investigations, other gentlemen may follow his example.

In the following table the distance of the end of the eighth cartilage from the sternum has been divided into eight compartments, each of which represents two centimetres except the first, in which are placed those cases where the eighth cartilage articulated with the sternum. The twelve children below 17 years of age have been omitted from this table, because their measurements would necessarily prove misleading. The accompanying diagram (fig. 1) will show at a glance the method of tabulation.

TABLE I.—*Distance of the Eighth Costal Cartilage from the Sternum.*

| | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | |
|--------|--------------|------------|--------------|--------------|----------------|--------------|------------|----|-----|
| ♂ { L. | 6 or 9·5% | 0 | 12 or 19% | 6 or 9·5% | 24 or 38% | 12 or 19% | 3 or 5% | 0 | —63 |
| ♂ { R. | 7 or 11% | 2 or 3% | 8 or 13% | 11 or 17% | 23 or 37% | 9 or 14% | 3 or 5% | 0 | —63 |
| ♀ { L. | 0 | 0 | 4 or 13% | 10 or 32% | 15 or 48·5% | 2 or 6·5% | 0 | 0 | —31 |
| ♀ { R. | 2 or 6·5% | 0 | 2 or 6·5% | 9 or 29% | 18 or 58% | 0 | 0 | 0 | —31 |

Two cases were recorded in which the seventh cartilage failed to quite reach the sternum. Besides the results recorded in the foregoing table, it must be remembered that twelve children were examined, in one of which the right eighth cartilage joined the sternum: it will thus be seen that out of 106 bodies the eighth cartilage articulated with the sternum six times (5·7 per cent.) on the left side, and ten times (9·5 per cent.) on the right.

The child in which the articulating right cartilage was found was a new-born male, and four other male children under 17 were examined in which the cartilage did not reach the sternum: these, added to the cases recorded in the table, show that in 68 male bodies of children and adults the eighth rib joined the sternum six times on the left side, and eight times on the right.

Five female children under 17 years were examined in addition to the 31 adult females already recorded: in these 36 female bodies the eighth cartilage was not seen to articulate with the sternum once on the left side, and only in two cases on the right.

Expressed as percentages, the results are as follows:—The eighth costal cartilage articulated with the sternum in 8·8 per cent. of male cases on the left side, and in 11·8 per cent. on the right. In females it articulated in 0 per cent. on the left side, and in 5·5 per cent. on the right.

The average distance of the eighth cartilage from the sternum will be best appreciated if the percentages are arranged in the form of diagrams. In these the distances in centimetres are placed at the bottom of the chart, while the percentages are at the side.

In comparing these four tables it will be noticed that those of opposite sides are very much alike, though in both sexes it is evident that the cartilage approaches nearer to the sternum on the right side than on the left. It will also be noticed that in the female tables there is a very long line between 6 and 8 centimetres, and little or nothing beyond; while in the male some 25 per cent. of the total cases are between 8 and 12 centimetres. This difference is to be expected when one remembers the greater size of the male thorax.

TABLE II.—*Adult Males.*
Left.

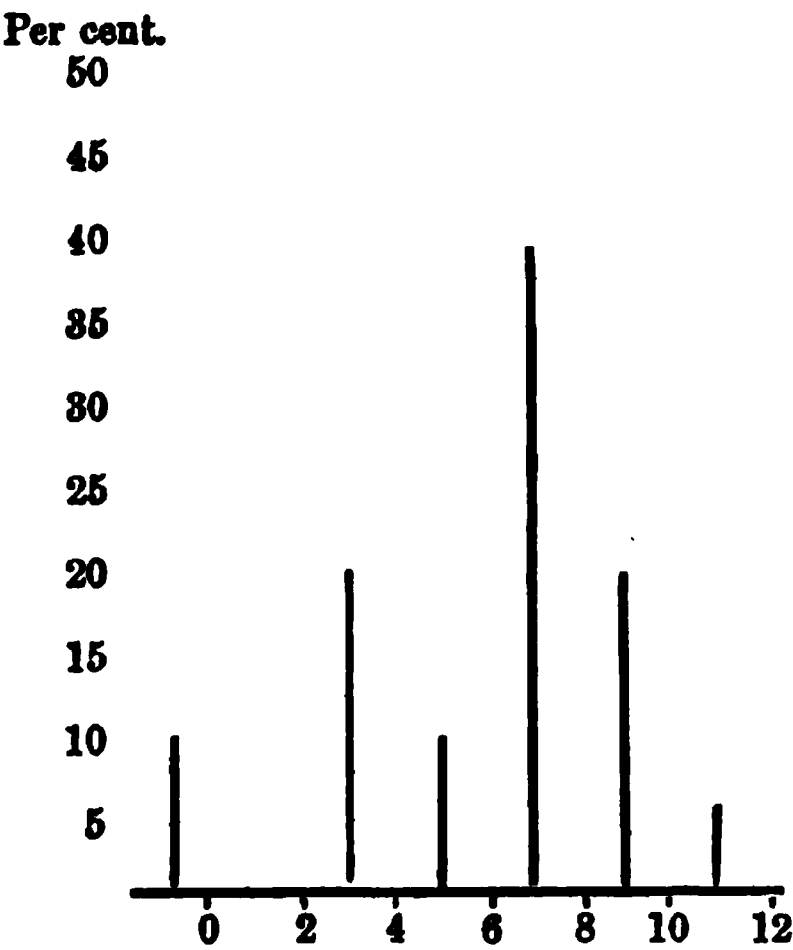


TABLE III.—*Adult Males.*
Right.

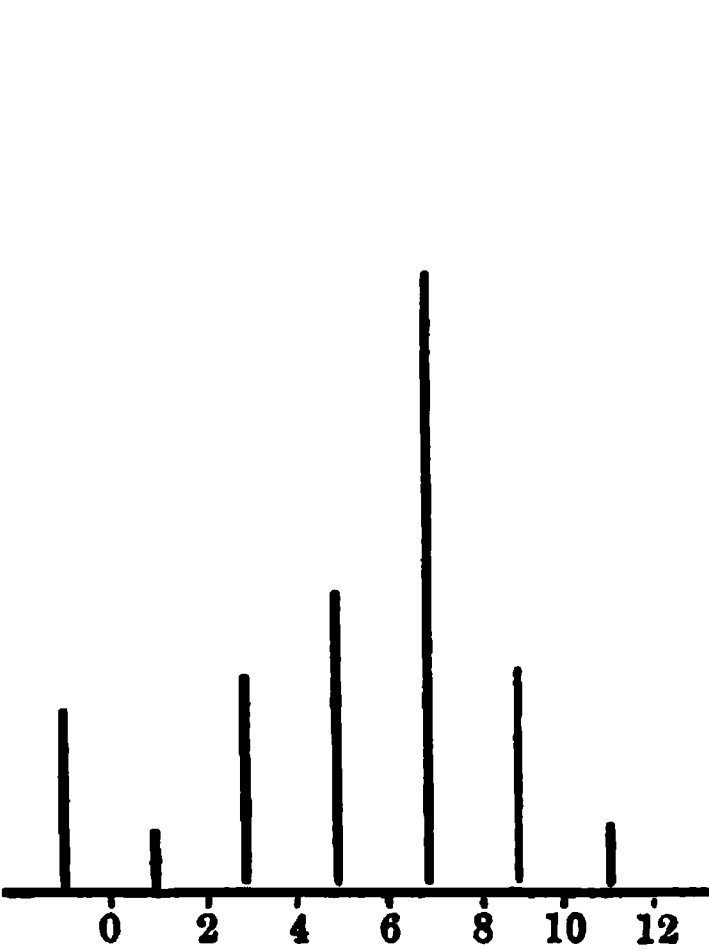


TABLE IV.—*Adult Females.*
Left.

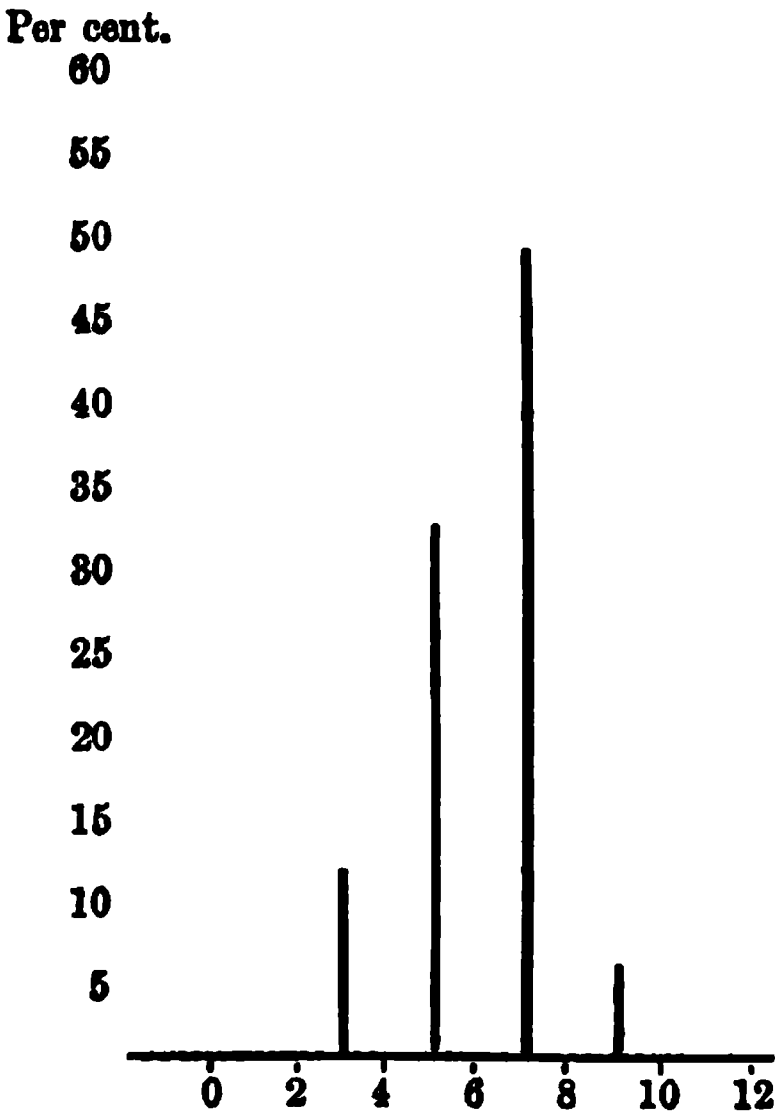
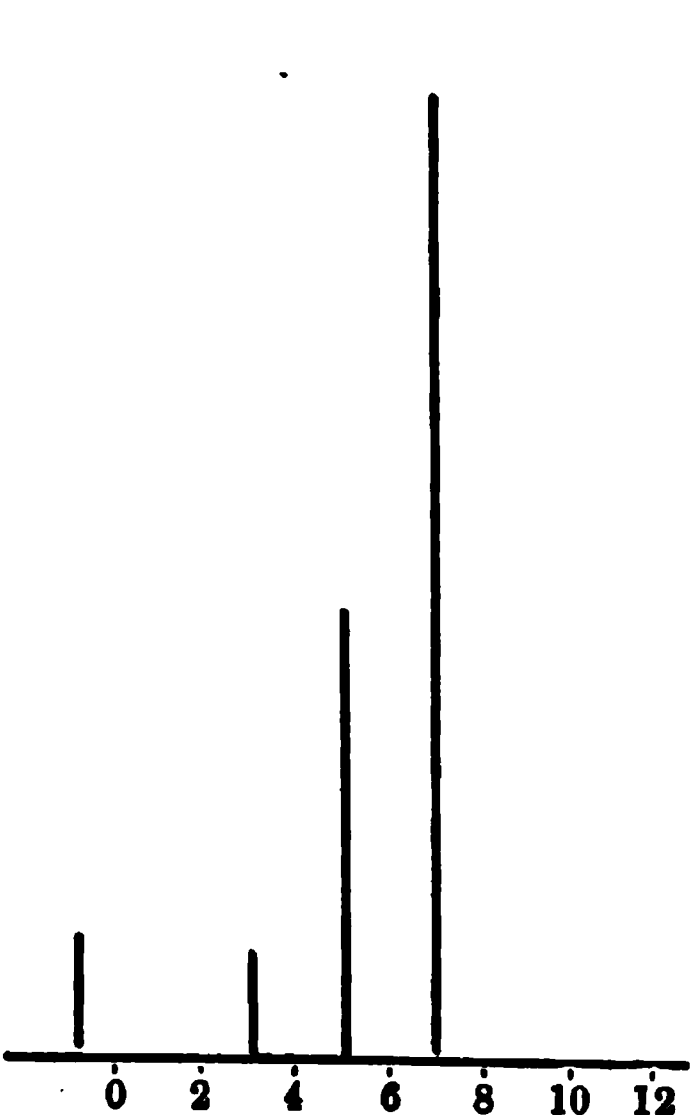


TABLE V.—*Adult Females.*
Right.



The greater unevenness of the female tables is probably due to their having been founded on a much smaller number of cases than the male ones.

The children's measurements have not been tabulated, because they are of all ages from birth to 17 years.

With regard to the condition of the rib-element of the first lumbar vertebra the result of the investigation is negative. In none of the cases in which the eighth rib joined the sternum was any peculiarity noticed in the vertebræ, though we do not feel sure, from the material at our disposal, that in every case irregularities were carefully looked for.

QUESTION II.

The relation of the great sciatic nerve to the pyriformis muscle.

Returns in answer to this question have been received from the following gentlemen:—

A. Low, Aberdeen University; E. H. Fraser, Edinburgh University; A. Keith, London Hospital; R. W. C. Pierce and H. E. Hewitt, St Thomas's Hospital.

For the purposes of classification the returns have been divided into the following three groups:—

Group A (fig. A) has the whole nerve emerging from the pelvis below the pyriformis.

Group B¹ (fig. B) has the nerve in two trunks, one of which (the external popliteal) pierces the pyriformis.

Group C (fig. C) consists of those cases in which the whole nerve pierces the pyriformis.

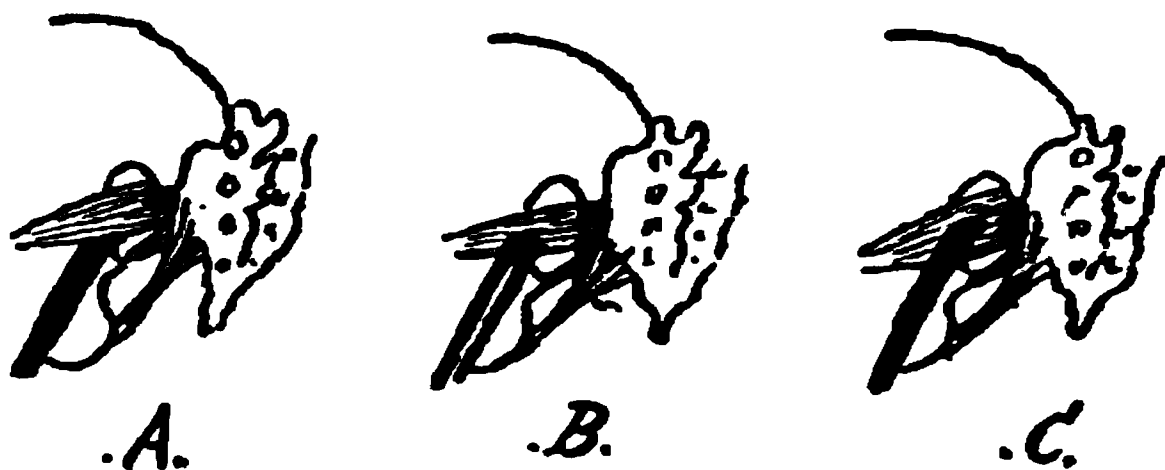


FIG. 2.

The total number of bodies examined was 69, which gives records of 138 observations. These are grouped in the following manner:—

| A. | B. | C. | |
|--------------|----------------|---------------|--------|
| 118 | 17 | 3 | = 138. |
| 85 per cent. | 12.3 per cent. | 2.2 per cent. | |

¹ The external popliteal nerve, after perforating the pyriformis, may or may not receive a communication from the internal popliteal. The statistics at our disposal do not allow us to tabulate this deviation.

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The following table shows the effect of the side on this small number of observations :—

| | A. | B. | C. | |
|----|--------------------|---------------------|--------------------|------|
| L. | 58 84 per cent. | 9 13 per cent. | 2 3 per cent. | =69. |
| R. | 60 87 per cent. | 8 11·5 per cent. | 1 1·5 per cent. | =69. |

In only 56 of these 69 bodies was the sex recorded, though, in justice to the observers, it should be noticed that neither side nor sex were asked for in the question. Of these 56 bodies 38 were males and 18 females. The results, arranged in tabular form, are as follows :—

| | A. | B. | C. | |
|--------|------------------------|-----------------------|----------------------|------|
| ♂ { L. | 34 (89·5 per cent.) | 3 (7·9 per cent.) | 1 (2·6 per cent.) | =38. |
| ♂ { R. | 35 (92·1 per cent.) | 3 (7·9 per cent.) | 0 | =38. |
| ♀ { L. | 12 (66·7 per cent.) | 5 (27·8 per cent.) | 1 (5·5 per cent.) | =18. |
| ♀ { R. | 16 (88·9 per cent.) | 2 (11·1 per cent.) | 0 | =18. |

The Committee is of opinion that these statistics are too few to found any definite conclusion upon.

QUESTION III.

The mode of termination of the internal plantar artery.

To this question returns of only 28 observations were received.

This number the Committee regards as too small to make any report upon.

QUESTION IV.

The arrangement and number (if possible) of the lymphatic glands accompanying the common, external, and internal iliac arteries.

Only three returns were received to this question. They were furnished by E. H. Fraser, Edinburgh University ; F. Barnes, Mason College, Birmingham ; and A. Keith, London Hospital.

These returns give a total of only 33 cases, and these are not altogether satisfactory. The Committee only feels justified in publishing a diagram which includes all the glands that have been recorded, and in giving provisional names to the chief groups, in the hope that at some future investigation the question may be set again, and that the recorders may have a common standpoint to observe from.

The deep epigastric gland seems a most constant one, and receives

the lymphatics accompanying the deep epigastric artery. The supra-crural gland is small, but appears to be usually present: whether it is the same gland that is described as occupying the crural canal must be determined at a future time; it seems to collect most of the lymphatics returning from the femoral glands. The other glands are arranged in groups, but seem to decrease in number with advancing years. Whether sex causes any variation in them we are unable to

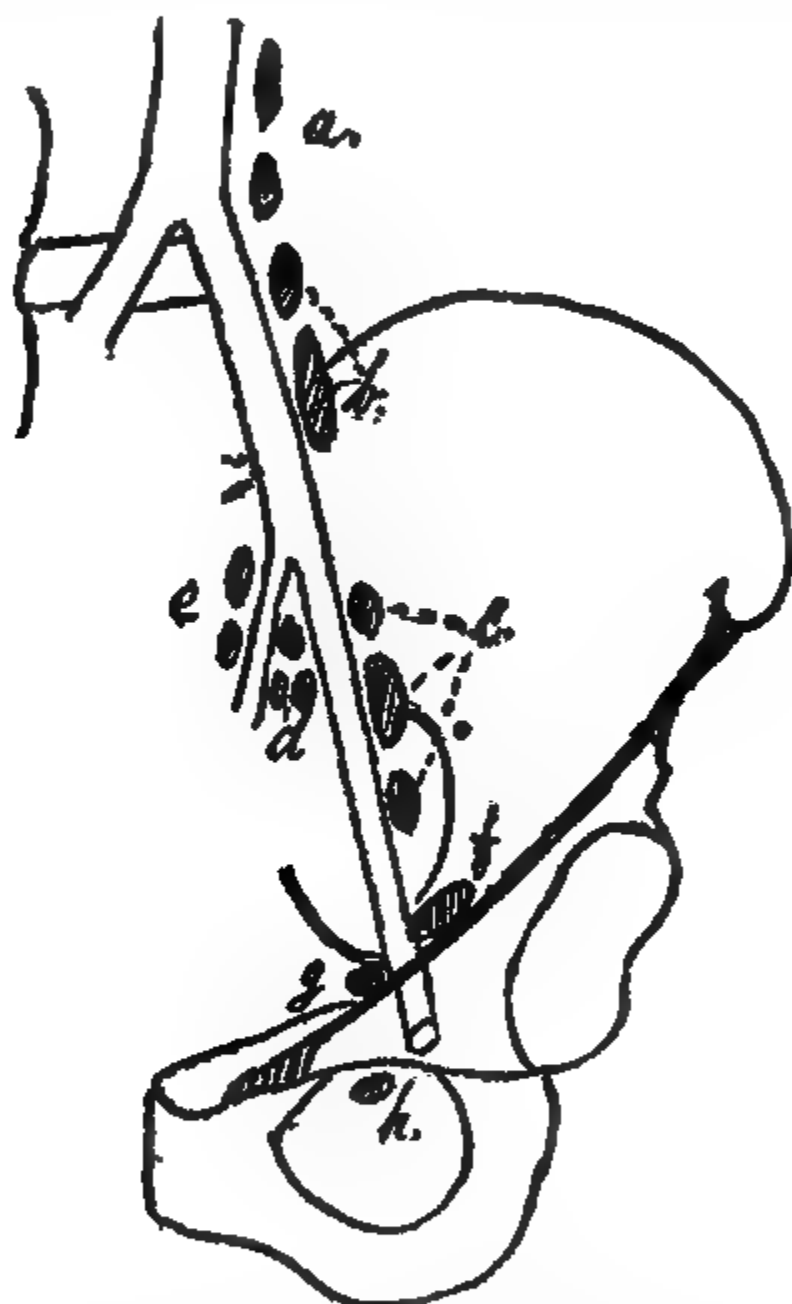


FIG. 3.—*a*, aortic glands. *b*, common iliac glands. *c*, external iliac glands. *d*, anterior internal iliac glands. *e*, posterior internal iliac glands. *f*, deep epigastric gland. *g*, supra-crural gland. *h*, obturator gland.

say. In any future investigation it will be most important that the side, sex, and age of each observation should be recorded, and it will greatly assist the compilers if an accurate diagram is made of each case.

QUESTION V.

The mode of origin of the branches of the internal iliac artery.

Reports on this question were received from the following gentlemen :—

A. Low, Aberdeen University; E. H. Fraser, Edinburgh University; G. Farmer, Oxford University; F. Barnes, Mason College, Birmingham; and A. Keith, London Hospital.

In issuing a synopsis of the returns to this question the Committee wishes to state that there are many reasons for regarding the results as purely tentative. In the first place, the observations are very few; in the second, they have been made sometimes on one side of the body only, sometimes on both; in the third place, in a structure so complicated as the internal iliac artery there is much room for error in the addition of the observations of many observers; and, in the fourth place, the variety in the division of this artery is so infinite that a proper classification, to fit in with the ordinary descriptions of text-books, is very difficult. Jastschinski¹ has felt the difficulty of classifying the forms of ramification when the internal iliac artery is regarded as ending in an anterior and posterior division, and has avoided the difficulty by studying first the various forms found in the newly-born child, and by then referring the forms found in the adult to these.

Before proceeding to study the following table, some explanation of the mode of classification will be necessary.

In the first place, we are glad to say that almost all the returns were forwarded to us in the shape of diagrams, and we are therefore sure that a uniform method of classification has been adopted. The first column records the side of the observation in all those cases in which it has been stated; when the R and L sides are joined by brackets, it means that these are observations on the two sides of the same body. The second column records the origin of the hypogastric trunk, a term we have found it necessary to apply to the common vessel so frequently present, from which the vesical, and often the hæmorrhoidal, uterine, and obturator arteries arise. As a rule, this trunk comes from the anterior division; but when the internal iliac divides low down, the hypogastric is, of course, a branch of the main trunk. In certain cases the vesical and hæmorrhoidal arteries come off separately, and in those cases no hypogastric trunk exists.

We have in all cases determined the commencement of the anterior and posterior divisions of the internal iliac as the place where the trunk containing the internal pudic leaves that containing the gluteal; hence the pudic is always a branch of the anterior division, and the gluteal of the posterior. The sciatic may be a branch of either division, or, as in one of our cases, may come off the internal iliac

¹ "Die typischen Verzweigungsformen der Arteria Hypogastrica," *Month. Internat. Journ. of Anat. and Phys.*, 1891, Bd. viii. pp. 111-126.

TABLE VI.—Male Bodies.

| Side. | Hypogastric Trunk. | Ilio-lumbar. | Lateral Sacral. | Gluteal. | Sciatic. | Pudic. | Middle Hemorrhoidal. | Inferior Vesical. | Superior Vesical. | Obturator. | Uterine. |
|----------------------------|--------------------------------------|--|--|------------------------------|---|------------------------------|--|---|--|---|----------|
| { R. L. | A.D. A.D. | I.I. (2) 1. P.D. 1. Sciatic. P.D. | (2) P.D. (1) P.D. (1) P.D. | P.D. P.D. P.D. | A.D. P.D. A.D. | A.D. A.D. | A.D. + Obt. A.D. | Hyp. T. Hyp. T. | Hyp. T. Hyp. T. | A.D. + M.H. A.D. | ... |
| { R. L. R. L. | A.D. A.D. I.I. | I.I. P.D. Obtr. | (2) P.D. (1) P.D. (2) I.I. | P.D. P.D. P.D. | P.D. A.D. A.D. | A.D. A.D. A.D. | Hyp. T. + Infl. Vea. A.D. A.D. Hyp. T. + Infl. Vea. | Hyp. T. + M.H. Hyp. T. Hyp. T. (2) 1. H.T. 1. M.H. | Hyp. T. Hyp. T. Hyp. T. | Deep Eplgast. Hyp. T. D. Eplg. I.I. | ... |
| { R. L. R. L. | A.D. A.D. A.D. None | P.D. I.I. I.I. (2) I.I. | (1) P.D. (2) P.D. (1) P.D. ... | P.D. P.D. P.D. P.D. | A.D. A.D. A.D. A.D. | A.D. A.D. A.D. A.D. | A.D. A.D. Hyp. T. A.D. + Obt. | Hyp. T. Hyp. T. Hyp. T. A.D. | Hyp. T. Hyp. T. Hyp. T. I.I. | A.D. D. Eplg. P.D. A.D. + M.H. | ... |
| L. L. R. | None A.D. A.D. | P.D. I.I. I.I. | (2) P.D. (1) P.D. (3) 1. I.I. 2. P.D. | P.D. P.D. P.D. | A.D. A.D. (2) A.D. | A.D. A.D. A.D. | A.D. A.D. Hyp. T. | A.D. Hyp. T. Hyp. T. | A.D. Hyp. T. Hyp. T. | A.D. A.D. D. Eplg. | ... |
| R. R. L. R. | I.I. A.D. None I.I. A.D. | I.I. P.D. I.I. P.D. | (2) 1. I.I. 1. P.D. (1) P.D. (1) P.D. | P.D. P.D. P.D. P.D. | A.I. A.D. A.D. (2) 1. A.D. 1 + Pud. | A.D. A.D. A.D. A.D. | Hyp. T. A.D. A.D. P.D. | Hyp. T. Hyp. T. A.D. Hyp. T. | Hyp. T. Hyp. T. A.D. Hyp. T. | A.D. A.D. A.D. A.D. | ... |
| R. R. R. R. L. | None A.D. I.I. A.I. A.I. | I.I. I.I. I.I. I.I. I.I. | (2) P.D. (2) P.D. (1) P.D. (1) P.D. (2) 1. I.I. 1. P.D. | P.D. P.D. P.D. P.D. | P.D. A.D. A.D. A.I. | A.D. A.D. A.D. A.I. | A.D. + Pudic. Obtr. Hyp. T. | I.I. Hyp. T. Hyp. T. Hyp. T. Hyp. T. | I.I. Hyp. T. Hyp. T. Hyp. T. Hyp. T. | I.I. A.I. Hyp. T. Hyp. T. A.I. | ... |

TABLE VI.—Male Bodies (continued).

| Side. | Hypogastric Trunk. | Ilio-lumbar. | Lateral Sacral. | Gluteal | Sciatic. | Pudic. | Middle Hemorrhoidal. | Inferior Vesical. | Superior Vesical. | Obturator. | Uterine. |
|-------|--------------------|--------------|-----------------|---------|----------|--------|----------------------|-------------------|-------------------|----------------|----------|
| L. | A.D. | P.D. | (2) P.D. | P.D. | A.D. | A.D. | A.D. + Sciat. | Hyp. T. | Hyp. T. | P.D. | ... |
| R. | A.D. | P.D. | (2) P.D. | P.D. | A.D. | A.D. | A.D. + Pudic. | Hyp. T. | Hyp. T. | ... | ... |
| R. | A.D. | I.I. | (1) P.D. | P.D. | P.D. | A.D. | Hyp. T. | Hyp. T. | Hyp. T. | A.D. | ... |
| R. | A.D. | I.I. | (2) P.D. | P.D. | A.D. | A.D. | Hyp. T. + Obt. | Hyp. T. | Hyp. T. | Hyp. T. + M.H. | ... |
| L. | A.D. | P.D. | (2) P.D. | P.D. | A.D. | A.D. | Hyp. T. + Sup. Ves. | A.D. | Hyp. T. + M.H. | ... | ... |
| R. | A.D. | I.I. | (2) 1 + I.L. | P.D. | I.I. | A.D. | A.D. + Pudic. | Hyp. T. | Hyp. T. | D. Epig. | ... |
| L. | A.D. | P.D. | (1) P.D. | P.D. | A.D. | A.D. | (2) 1. A.D. | (2) Hyp. T. | Hyp. T. | Hyp. T. | ... |
| L. | None | I.I. | (2) P.D. | P.D. | A.D. | A.D. | 1. P.D. + L. Sac. | A.D. | A.D. | D. Epig. | ... |
| L. | None | I.I. | (1) P.D. | P.D. | A.D. | A.D. | ... | A.D. | I.I. | P.D. | ... |
| R. | None | I.I. | (2) 1. P.D. | P.D. | A.D. | A.D. | A.D. | A.D. | A.D. | I.I. | ... |

Female Bodies.

| | | | | | | | | | | | |
|----|------|------|----------|------|------|------|--------------------|---------|---------|-----------------|----------------|
| R. | A.D. | I.I. | (1) P.D. | P.D. | A.D. | A.D. | A.D. | Hyp. T. | Hyp. T. | A.D. | Hyp. T. |
| L. | I.I. | I.I. | (1) I.I. | P.D. | A.D. | A.D. | Pudic. | Hyp. T. | Hyp. T. | P.D. | Hyp. T. |
| R. | A.D. | I.I. | ... | P.D. | A.D. | A.D. | Pudic. | Hyp. T. | Hyp. T. | Hyp. T. | Hyp. T. |
| L. | A.D. | P.D. | (2) P.D. | P.D. | P.D. | A.D. | A.D. | Hyp. T. | Hyp. T. | A.D. | + Inf. Ves. |
| R. | A.D. | P.D. | (2) P.D. | P.D. | A.D. | A.D. | A.D. | Hyp. T. | Hyp. T. | A.D. | (2) 1. Hyp. T. |
| L. | I.I. | I.I. | (1) I.I. | P.D. | A.D. | A.D. | Hyp. T. + Uterine. | Hyp. T. | Hyp. T. | above vesicals. | 1. A.D. |

between the two divisions. In those cases in which two arteries, nearly equal in size, come off by a common trunk, we have indicated the fact by putting the second artery with a + sign in front of it.

In order to render our meaning more clear, we give diagrams of two internal iliacs, in one of which the division into anterior and posterior trunks is high, in the other low.

In fig. 4 there is no hypogastric trunk, as the arteries which usually compose it spring separately from the anterior division.

In fig. 5 the hypogastric trunk is a branch of the internal iliac before its division.

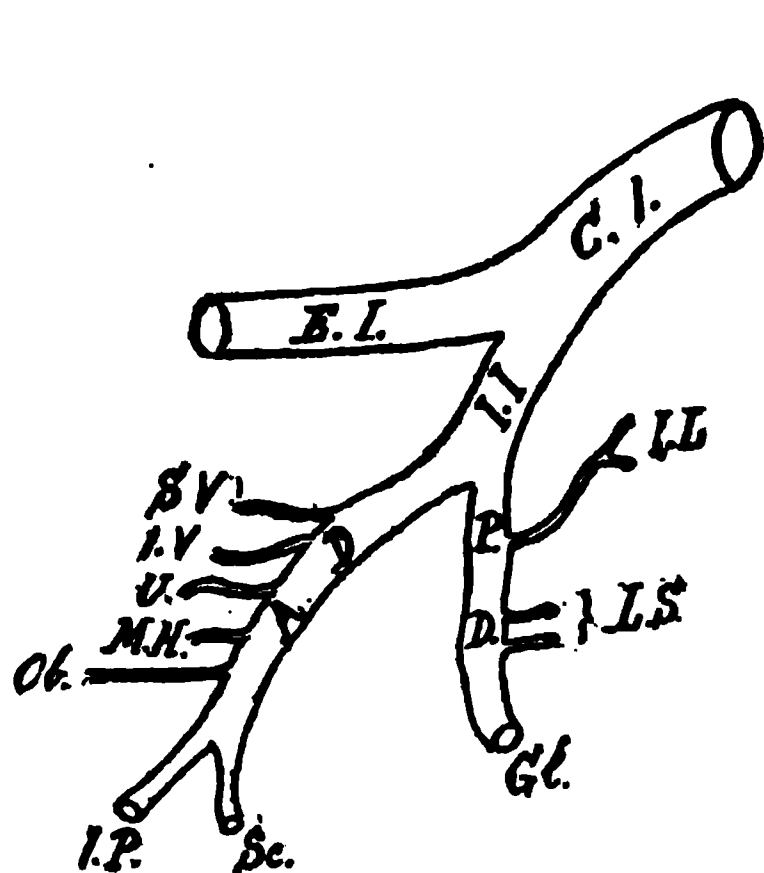


FIG. 4.

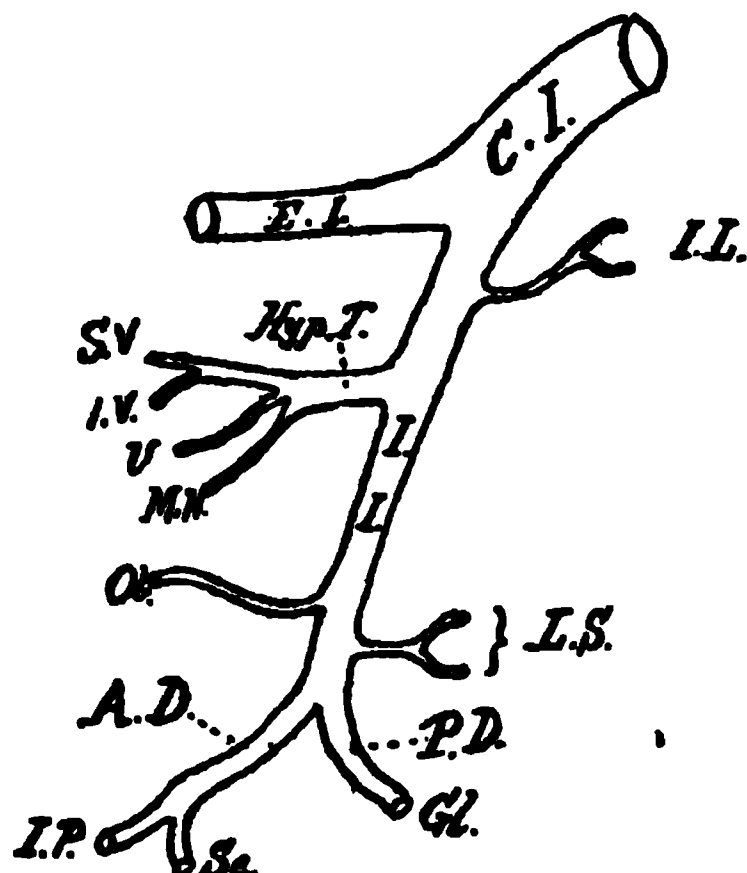


FIG. 5.

Hypogastric trunk.—There are records of 56 observations of this vessel. In 37 (66 per cent.) it was a branch of the anterior division; in 13 (23·3 per cent.) no trunk was present; while in the remaining 6 (10·7 per cent.) it came from the internal iliac before its division into two.

Ilio-lumbar.—57 observations are recorded. In 35 (61·4 per cent.) it rose entirely from the internal iliac: in one of these cases the artery was double; in 17 (29·8 per cent.) it rose directly from the posterior division; in 2 cases it rose from the posterior division in common with the lateral sacral. In 2 cases, besides the one already recorded, the artery was double: in the first of these one twig rose from the posterior division, and the other from the sciatic; in the second, the upper twig came from the internal iliac, and the lower from the posterior division. In one case the ilio-lumbar was a branch of the obturator, itself a branch of the internal iliac.

Lateral sacral.—53 observations. In 27 (50·9 per cent.) the two arteries of one side rose by a common trunk; in 25 (47·2 per cent.) there were two distinct arteries on one side, while in one case three arteries were present. Of the 27 cases in which the single trunk was present, it came from the posterior division in 25 (92·6 per cent.), and from the internal iliac in 2 (7·4 per cent.). Of the 25 cases in

which there were two arteries, they both came from the posterior division 17 times (68 per cent.), both from the internal iliac once (4 per cent.), while in the remaining 7 instances they rose from different parts, the upper one usually coming from the internal iliac, the lower from the posterior division. In 9 cases, as has already been recorded, one or both the lateral sacrals came off in common with the ilio-lumbar.

The Gluteal artery, according to our method of classification, must always be the terminal branch of the posterior division.

The Sciatic artery, as Jastschinski has pointed out, may be a branch of the anterior or posterior division, or may come off from the internal iliac between these divisions. We have 56 observations of it: in 42 of these (75 per cent.) it rose from the anterior division; in 12 (21·4 per cent.), from the posterior division; while in only one case (1·8 per cent.) did it come off from the internal iliac. Occasionally (3 cases) the artery is double, and in one of these one branch came from the anterior, and the other from the posterior division; this case we have, therefore, not included in either category.

The Internal Pudic is necessarily always a branch of the anterior division. It is remarkable that no cases of accessory pudics have been recorded in our returns.

Middle Hæmorrhoidal.—45 observations. In 15 cases (33·3 per cent.) it rose by itself from the anterior division; in 10 (22·2 per cent.) it came off separately from the hypogastric trunk; in 6 (13·3 per cent.) it had a common origin with the pudic; in 4 (8·9 per cent.) it rose in common with the obturator; in 2 cases (4·4 per cent.), in common with the sciatic (in 1 of these the sciatic was a branch of the posterior division); in 2 cases, in common with the inferior vesical; in 2 with the uterine, and in 1 with the superior vesical. In 2 cases it rose by itself from the posterior division, and in 1 case there were 2 middle hæmorrhoidal arteries, 1 coming from the anterior division, the other from the posterior division in common with the lateral sacral.

Inferior Vesical.—58 observations. In 40 cases (68·9 per cent.) it rose as a separate vessel from the hypogastric trunk; in 13 (22·4 per cent.) as a separate vessel from the anterior division; in 2 (3·5 per cent.) as a separate vessel from the internal iliac. In 3 cases (5·2 per cent.) the vessel rose in common with others, twice with the middle hæmorrhoidal, and once with the superior vesical: in the 2 former cases, however, there were 2 inferior vesical arteries, 1 of which came directly from the hypogastric trunk.

Superior Vesical.—58 observations. In 44 cases (75·9 per cent.) it rose from the hypogastric trunk: in 2 of these cases the artery was double; in 9 cases (15·5 per cent.) it came from the anterior division, in 1 of these the artery was double; in 4 cases (7 per cent.) it came from the internal iliac; and in 1 case, in common with the middle hæmorrhoidal, from the hypogastric trunk.

Obturator.—55 observations. In 20 cases (36·4 per cent.) it rose as a separate trunk from the anterior division; in 10 (18·1 per cent.) from the deep epigastric; in 9 (16·4 per cent.) separately from the hypo-

gastric trunk ; in 8 (14·5 per cent.) from the posterior division ; in 5 (9·1 per cent.) from the internal iliac before its division ; while in 3 cases (5·4 per cent.) it rose in common with the middle hæmorrhoidal, 2 of these coming from the anterior division, and 1 from the hypogastric trunk. In connection with the origin of the obturator from the deep epigastric, we find that out of 138 subjects examined at Guy's Hospital¹ the obturator was only seen to rise from the deep epigastric 11 times (8 per cent.) ; while in Quain's *Anatomy*² it is stated that this origin is found in nearly 30 per cent. The percentage which this investigation gives (18·1 per cent.) is nearly midway between these, but it is evident that further observation is necessary.

Uterine.—18 observations. In 9 cases (50 per cent.) the artery rose from the hypogastric trunk as a single separate vessel ; in 3 (16·9 per cent.) it was a separate branch of the anterior division ; in 3 (16·9 per cent.) it came off with the inferior vesical from the hypogastric trunk ; in 1 case it rose in common with the middle hæmorrhoidal from the anterior division. In 2 cases there were 2 uterine arteries ; in the first of these 1 arose from the hypogastric trunk, and the other from

the anterior division ; in the second, 1 rose with the inferior vesical, and the other with the middle hæmorrhoidal.

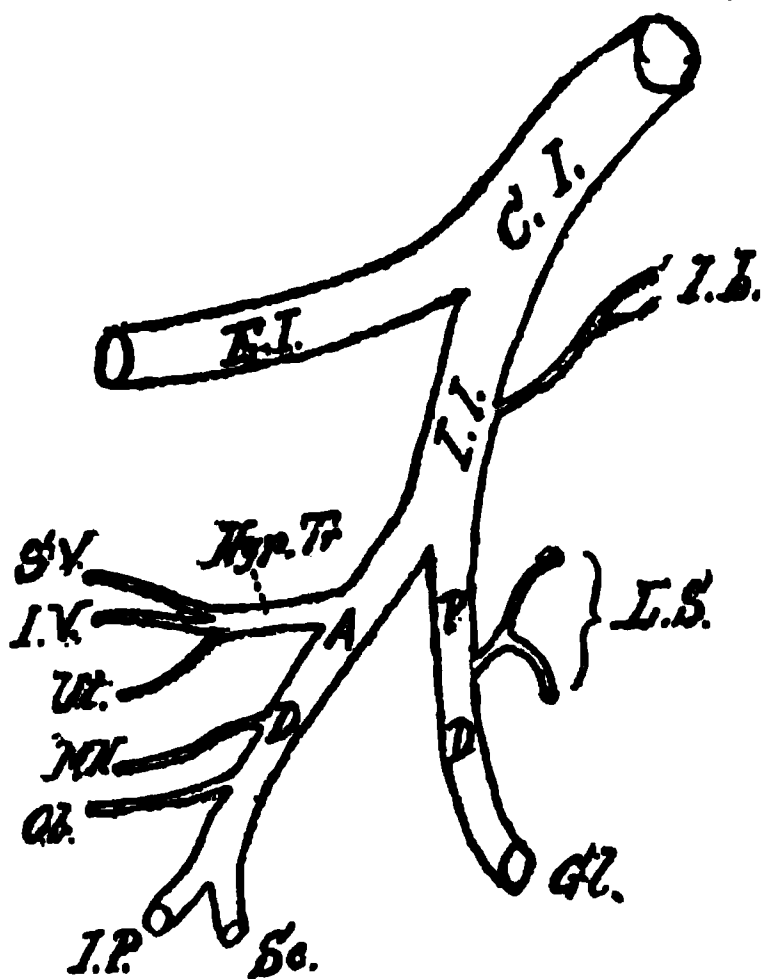


FIG. 6.

According to this investigation the following description of the origin of the branches of the internal iliac would be most likely to be accurate. The ilio-lumbar is a branch of the internal iliac before its division into two trunks.

The hypogastric trunk is a branch of the anterior division, and breaks up into superior vesical, inferior vesical, and uterine.

The middle hæmorrhoidal is a separate branch of the anterior division. The obturator is the same.

The sciatic and internal pudic are the terminal branches of the anterior division.

The lateral sacrals are two on each side : they rise from the posterior division, and are as likely to come off by a single common trunk as by two separate vessels.

The gluteal is the terminal branch of the posterior division.

We add a figure of an internal iliac artery which this investigation makes us regard as typical.

¹ *Guy's Hospital Reports*, 1871, vol. xvi. p. 135.

² 10th edition, vol. ii. part ii. p. 476.

SOME POINTS IN THE ANATOMY OF THE DORSUM OF THE HAND, WITH SPECIAL REFERENCE TO THE MORPHOLOGY OF THE EXTENSOR BREVIS DIGITORUM MANUS. By E. BARCLAY SMITH, M.A., M.D., *Demonstrator of Anatomy in the University of Cambridge.*

CONSIDERABLE ingenuity and much labour have been expended in order to determine what is to be regarded as the primitive arrangement of the muscles of the forearm and hand, to trace the successive modifications which the individual muscles in this region have undergone whereby the eventual disposition in man has been attained, and to identify the homologous counterparts of these muscles in the lower limb.

In the lower limb a short digital extensor confined to the foot is normally present; occasionally a muscle makes its appearance in the upper limb, confined to the hand, and presenting a remarkable analogy as far as its anatomical disposition is concerned with the extensor brevis digitorum pedis.

The precise significance of this occasional extensor brevis digitorum manus is a matter of some considerable interest.

Macalister, in his description of the extensor brev. dig. pedis, states that "the corresponding muscle in the upper limb is only represented by rudimental slips, of which that for the ring finger is most frequently present." The more generally received opinion, however, seems to be, that the ext. brev. dig. pedis is represented in the upper limb by muscles which are normally present, viz., the extensor indicis, with the possible addition of the extensor minimi digiti and one or other of the thumb extensors. This view was formulated by Meckel early in the century, and Humphry practically comes to the same conclusion in his considerations on the muscles of vertebrate animals. If we are to regard this scheme as the correct one, then the occasional ext. brev. dig. manus cannot be regarded as the true homologue of the ext. brev. dig. ped., close though the simulation may be. Brooks,¹ founding his

¹ *Studies from the Museum of Zoology in University College, Dundee.*

arguments on the muscular arrangements in Menobranchus, Hatteria, and Ornithorhynchus, endeavours to prove that the extensor sheet in the forearm undergoes a primary delamination, resulting in the formation of a superficial and deep extensor of the digits; that the deep extensor has primitively a much lower attachment than in man; and that the human disposition has been attained by an axial migration of this muscle and its segmentation into separate slips. He considers the ext. brev. dig. manus, when it makes its appearance in man, to be the representative of the metacarpal heads of the deep extensor. In other words, he looks upon the ext. brev. dig. manus as resulting from a secondary and occasionally persisting delamination of the deep extensor, and presumably, therefore, only a partial representative of the ext. brev. dig. pedis.

It is obvious, from this brief recapitulation of current opinion, that the ext. brev. dig. manus presents us with a difficult problem to solve, both as regards its morphological relationships to the general musculature of the forearm, and its possible homologue in the lower limb.

I have so far taken it for granted that the term 'ext. brev. dig. manus' refers to a well-defined and easily recognisable muscle. But cases such as that described by Wood in the *Proceedings of the Royal Society*, where the term is obviously an appropriate one, are exceedingly rare. On the other hand, muscular slips confined to the dorsum of the hand, and differentiated to a greater or less degree from the m. interossei dorsales, are exceedingly common. Are we to regard these commonly occurring slips as a rudimentary condition of the fully developed muscle, as described by Wood? There seems to be no general consensus of opinion. Gruber describes them as accessory extensors. Otto describes a slip connected with the index finger as an '*extensor indicis anomalus*.' Brooks warns us not to mistake the ext. brev. dig. manus for occasional slips of the m. inteross. dors., with which it may be confounded; but where the line of demarcation is to be drawn, it is difficult to see.

Having frequently noticed muscular slips which, although contained in the inter-metacarpal spaces in the back of the hand, had no very definite connection with the m. inteross. dors., I determined to investigate them carefully, in order to gain some

approximate idea of the frequency with which they occur, and if possible to gain some insight into their precise significance.

With this object in view I have carefully examined some fifty hands. The investigation entailed a careful dissection of all the structures on the dorsum of the hand, a proper appreciation of which has led me to the conclusion that these muscular slips are very much more frequently present than may be generally supposed,—to such an extent indeed, that they must be regarded as an almost normal condition in man.

It is important to recognise the following strata in this region:—

(1) On removing the subcutaneous tissue a *tendino-fascial layer*, comprising the extensor tendons and the membranous fascia in which the tendons are embedded, is exposed to view. I have thus designated this stratum, as it may be cut through transversely below the posterior annular ligament, and reflected downwards as a continuous sheet. Defined in this manner, the fascial component of the sheet is seen to clothe the tendons on their superficial and deep aspects, and to stretch between them as a membrane whose fibres are for the most part transversely disposed. Towards the digital clefts the membranous character of the fascia becomes lost, and is replaced by the loose fatty tissue occupying the intervals between the knuckles.

(2) Beneath the tendino-fascial layer, between it and the metacarpal bones, is a fascial layer which may be easily separated from the underlying bones. The fibres are rather loosely woven, have no very definite arrangement, and together form a somewhat tenuous though distinct sheet. Traced on to the carpus, the identity of this layer becomes lost, as it cannot be separated from the carpal ligaments, to which it is closely adherent. Towards the distal ends of the inter-metacarpal spaces it merges into the loose fat found in these situations (*vide supra*). This fascial layer is passed unnoticed by the text-books; but as it has an important bearing, to which I shall presently refer, I have thought fit to distinguish it as the *supra-metacarpal fascia*.

(3) Stretching between adjoining metacarpal bones, to which it is closely adherent, is the *interosseous fascia*. The fibres of this fascia have a general transverse disposition; and although its thickness and strength vary considerably in

different subjects, yet it is usually well marked for the greater part of the inter-metacarpal space. Towards the distal end of the space this fascia becomes thin and indistinct, finally losing its identity, like the strata superficial to it, in the fatty pads occupying the intervals between the knuckles, and clothing the tendons of the *m. inteross. dors.*

The dorsal interosseous (metacarpal) vessels lie superficially to the interosseous fascia, deeply to the supra-metacarpal fascia; in fact, the plane of these vessels furnishes a useful guide to distinguish between the two layers.

The *m. inteross. dors.* are usually closely adherent to the deep aspect of the interosseous fascia, from which they may be said to take origin. The proximal attachments of these muscles frequently invade the bases of the metacarpal bones.

If the supra-metacarpal fascia is detached from the carpus, and carefully reflected towards the fingers so as to expose its deep aspect, it is frequently found that, towards the distal ends of the inter-metacarpal spaces, this fascia is bound down by small fan-shaped muscle slips, which are adherent to its deep surface, and whose converging fibres are closely associated with the insertions of the *m. inteross. dors.*

In other cases slips may be found occupying the whole length of the inter-metacarpal space, and invading the base of the metacarpus and dorsal aspect of the carpus. Such slips may be distinguished from the underlying *m. inteross. dors.* by the interosseous fascia which intervenes between them, by the direction and length of their fibres, and by the fibres having no direct attachment to the sides of the metacarpal bones. The direction of these slips usually corresponds to the long axis of the inter-metacarpal space, but they are frequently obliquely disposed, and overlap one or other of the metacarpal bones to a greater or less extent. Their extensions on to the base of the metacarpus and to the carpus are usually adherent to the underlying bones and ligaments by a tendinous expansion. When two or more such slips are present, the tendinous expansions which constitute their proximal attachments are inseparable one from the other, and may be regarded as common.

Between these two sets of cases, which may be termed the extremes of the conditions which I met with, I have found every

intermediate stage in the form of slips occupying the plane of separation between the supra-metacarpal and interosseous fasciae, and extending for variable distances from the distal to the proximal ends of the inter-metacarpal spaces. When these slips are short, they are usually adherent to the deep aspect of the supra-metacarpal fascia. If they encroach beyond the proximal limits of the inter-metacarpal space, they are usually adherent to the underlying bone.

The following is a summary of the cases in which I have found these slips present in one condition or another.

Of the 50 hands examined they were present in 35 (70 per cent.), no trace being found in 15 (30 per cent.).

Of the 35 cases,

a slip was present in the 2nd inter-metacarpal space in 23 cases.

| | | | | | | | |
|---|---|---|-----|---|---|----|---|
| " | " | " | 3rd | " | " | 14 | " |
| " | " | " | 4th | " | " | 4 | " |
| " | " | " | 1st | " | " | 1 | " |

In 28 cases a slip was found in one inter-space only.

| | | | | | |
|---|---|---|------------|---|-------------------|
| " | 6 | " | slips were | " | two inter-spaces. |
| " | 1 | " | " | " | three |

The distal attachments of these slips were for the most part in common with those of the m. inteross. dors., to which they formed, as it were, a third head. In some cases, however, they could be traced independently into the general extensor expansion. In one case a slip, with a well marked muscle belly at the proximal end of the inter-metacarpal space, ended in a fine tendon which was lost in the fatty pad between the heads of the metacarpal bones. In another case, where two well marked slips occupied the 2nd and 3rd inter-space, and had a common tendinous attachment to the back of the carpus, the one in the 3rd inter-space divided into two tendons, which were traceable into the extensor expansions of the medial and annular digits.

Muscular slips occupying the whole extent of the inter-metacarpal spaces, and extending on to the base of the metacarpus and carpus, have frequently been noticed by other observers. I need only refer to a case described by Gruber, since the plate¹ in which he illustrates them gives a very good idea of their

¹ *Beobachtungen, a.d. Anatomie*, Heft vi. Tab. ii. fig. 5.

usual disposition. A figure in the *Guy's Hospital Reports*,¹ illustrating a case in which two small muscles arose from the fascia on the back of the carpus, and occupied the 4th and 2nd inter-spaces, might have been drawn from one of my specimens, so close is the resemblance.

One of the chief points of interest in connection with these muscle slips centres in their nerve supply. I set to work to determine this with a perfectly unbiassed mind, endeavouring in each case to trace the nerve from the muscle slip to its source. In many cases the slips were so small that tracing nerve strands in connection with them was a physical impossibility. In other cases, however, I was more successful. In no case was I able to trace nerve fibres from the muscle slip to the pseudo-ganglion on the trunk of the post. inteross. nerve, but in several instances I found fine twigs accompanying the dorsal interosseous arteries, traversing the bicipital origins of the m. inteross. dors., and derived from the deep branch of the ulnar nerve in the palm.² The cases in which the nerve supply was most satisfactorily defined were those in which the slips had a definite attachment to the back of the carpus.

This nerve supply is certainly worthy of remark, in that a muscle slip, undoubtedly extensor in disposition, presumably extensor in function, receives its supply from a nerve trunk, which is essentially flexor in its distribution.

Although I have met with no case in which an extensor brevis digitorum manus was present in such a fully developed condition as that described and figured by Wood, yet the cases which I have described may possibly throw some light upon the origin of such a muscle.

The occurrence of an extensor brevis digitorum manus in man is open to any one of the following interpretations:—

(a) That it is an atavistic variation of a muscle normally represented in the foot.

(b) That it is a persistent deep delamination of the deep digital extensor, this deep delamination being represented by metacarpal attachments of the deep extensor in some animals.

¹ Vol. xlvii. p 312.

² Rauber has described communicating filaments between the ulnar and post. inteross. nerves, accompanying the perforatory arteries.

(c) That it is a derivative of the dorsal interosseous musculature.

(d) That it is derived from a new muscle germ.

(a) If we adopt this interpretation, we must presume that at one time or another there were three strata of digital extensors in both the upper and lower limb; and further, that the intermediate stratum has disappeared in the lower limb, while the deep stratum persists in the lower limb, but normally disappears in the lower limb. As there is absolutely no evidence in support of such an hypothesis, it is needless to discuss it.

(b) That an ext. brev. dig. manus represents the metacarpal attachments of the deep digital extensor is at first sight a very plausible explanation. In support of this theory, the occasional attachments of the ext. brev. dig. ped. to the metatarsal bones, as described by Ruge, are certainly very significant. A closer examination, however, shows that this explanation is scarcely a tenable one. If the ext. brev. dig. manus represents the metacarpal attachments of the deep digital extensor, then a delamination must have involved this musculature, the superficial component tending to migrate axially, the deep component tending to retain its original position on the dorsum of the manus. In other words, we must assume a tendency to a trilaminar condition of the extensor muscles (digital) of the forearm. There is, however, but little evidence to show that such a tendency is a common one. In no mammal can I find incontrovertible evidence of this hypothetical arrangement, with the exception perhaps of *Bradypus tridactylus*, where a third or deep extensor is represented by a short extensor digitorum on the back of the manus. The interosseous muscles, however, are absent in this animal; and, as Macalister¹ points out, the short extensor undoubtedly represents the dorsal displacement of these muscles, the displacement being due to the very close approximation of the metacarpal bones.

What is to be regarded as the primitive arrangement of the extensor muscles in the distal segments of the two limbs is an exceedingly difficult matter to determine. At present we are not justified in assuming more than that there is a general tendency for the digital extensors to delaminate into superficial

¹ "Myology of *Bradypus tridactylus*," *Annals and Magazine of Natural History*, 1869.

and deep strata, and, of the two, the deep stratum is much the less stable. Ruge has brought forward cogent evidence to prove that the human disposition of the ext. brev. dig. pedis is the result of a distal migration of the elements of the deep stratum. Brooks would have us believe that a migration has affected the corresponding stratum in the upper limb in an opposite direction. If both are right, which is to be regarded as the more primitive arrangement of the digital extensors in man,—that of the hand, or that of the foot? Migration certainly plays an important part in the mutations to which the muscular system is subject; but to make too extensive a use of such an explanation is fraught with danger, and is liable to lead to erroneous conclusions. To account for the human disposition of any particular muscle or system of muscles as the result of migration, is rather too easy a solution of a problem teeming with difficulties. With a carefully selected series of animals, the theory of migration will enable us to establish any primitive type that it may best please us to formulate.¹

In endeavouring to trace the modifications which the members of any muscle group have undergone, and thereby to establish what may be regarded as an ancestral type, presumably simple, and to which we must refer all existing arrangements, many factors in addition to migration must be taken into account, as responsible to a greater or less degree for the complex resultant in any particular case. For example, contiguity of development is one of the most potent causes for the implantation of a muscle on any particular bony surface. And, assuming that the developments of the muscular and skeletal systems do not necessarily run on identical or even parallel lines, this cause alone may lead to an infinite variety of muscular attachment. The fact that in the short-thighed seal the adductor magnus has a tibial attachment, does not justify us in concluding that this muscle has a universal tendency to encroach beyond the limits of the distal end of the femur, and that in man the tibial attachment may be described as having been lost. Again, we are apt to consider

¹ By a curious coincidence, two papers were read at the same meeting of the Anatomical Society, the one to show that the deep extensors in the forearm had migrated proximally, the other that the same group of muscles tended to migrate in the opposite direction.

that segmentation and delamination of a primitive muscle-mass necessarily take place in lines and planes which are more or less rigid, without taking into account the possibility of the lines of cleavage being largely influenced by individual requirements.

If we are met with these difficulties when endeavouring to identify any particular muscle in the one limb, and to assign it to its proper place in the general scheme of appendicular development, the task is still more formidable if we seek for its exact homologue in the lower limb. The hind limb can in nowise be regarded as the exact counterpart of the fore limb. From their first appearance the particular functions each limb has been called upon to play have been different: their respective developments have taken place along routes which, though at one time converging, at another time diverging, have never been identical. Serial homology, when applied to the appendicular musculatures, though undoubtedly useful in that it indicates a certain parallelism of development, must consequently not be too exacting.

The attachments and the general disposition are useful but not infallible homological guides. The *ext. brev. dig. pedis* furnishes a case in point. This muscle represents the deep digital extensor in the leg, while the corresponding muscle in the arm is represented by the *extensor indicis*.¹ We are not justified in insisting upon a more definite homology than this. At first sight the hallucial slip of the *ext. brev. dig. pedis*, sometimes differentiated as the *extensor brevis hallucis*, appears to be the exact counterpart of the *ext. brev. (primi internodii) pollicis*. The two muscles are remarkably alike as far as their disposition in man is concerned: they are both relatively short muscles, they are both deep, and their distal attachments are identical. The homological relationship between the two is, however, more apparent than real. The *ext. brev. pollicis* is a muscle of extremely late appearance; it is peculiarly human, and all the evidence points to its being a segmentation product of the *ext. oss. metacarp. pollicis*, its appearance being foreshadowed in the

¹ The *extensor minimi digiti* may be left out of account; for although there are good reasons for supposing that it is derived from the deep digital extensor, yet it has no normal representative in the leg.

anthropoid by an extension of the ext. oss. metacarp. pollicis on to the proximal phalanx of the thumb. In the case of the ext. brev. hallucis there is no evidence to show that it is similarly related to an ext. oss. metatars. hallucis. This leads us to the consideration of the probable homologue of the ext. ossis metacarpi pollicis. In Quain's table of muscular homologies, the tibialis anticus is regarded in this light. Assuming, for the sake of argument, that this view is the correct one, there is no evidence to show that the ext. brev. hallucis is a derivative of the tibialis anticus; while the slip which the latter muscle so frequently sends to the proximal phalanx of the great toe asserts a reasonable claim to be considered as the homologue of the ext. brev. pollicis. Further, the homology between the ext. oss. metacarp. pollicis and the tibialis anticus is an exceedingly doubtful one. The chief reason for such an assumption is the similarity between the distal attachments of the two muscles, and even in this respect they are not identical. The two are on entirely different planes: the tibialis anticus is, and always has been, a superficial muscle, while the extensor ossis metacarpi pollicis is undoubtedly a deep delamination. Is there any evidence to show that an ext. ossis metatarsi hallucis, distinct from and on a deeper plane than the tibialis anticus, is a universal tendency? Brooks suggests that this is the case, and argues, in favour thereof, that such a muscle occasionally makes its appearance in man. An ext. oss. metatars. hallucis, however, is an exceedingly rare anomaly; and even when it is present, it cannot be regarded as directly atavistic, since it does not represent a normal mammalian tendency. Brooks certainly describes such a muscle in *Menobranchus* and *Hatteria*. In *Menobranchus*, however, the distal attachment of the tibialis anticus (tibial sector of the superficial plane of muscle) is confined to the tibia, and the ext. ossis metatarsi hallucis¹ continues the direction of the tibialis anticus, and looks suspiciously like the cut-off distal end of that muscle. In *Hatteria* the muscle described under the name ext. oss. metatars. hall. is a slip derived from the deep digital extensor, attached to the first metatarsal, and is not an independent muscle. A search through the literature dealing with the myology of the

¹ The title is a courtesy one, as the muscle is inserted into metatarsal II, the hallux being suppressed.

lower limb has convinced me, on the other hand, that such a muscle in most if not in all mammals is conspicuous by its absence. Amphibian and reptilian characteristics, at best of a doubtful nature, do not afford a very sure foundation for the hypothesis that an ext. ossis metatarsi hallucis is a normal feature in the myological architecture of the lower limb, at any rate as far as its recent phylogenetic history is concerned. The lack of evidence in support of a potential ext. oss. metatars. hallucis militates greatly against the assumed homology between the ext. brev. hallucis and the ext. brev. pollicis. Occasionally, but rarely, the ext. indicis is furnished with two tendons, the inner of the two passing to the pollex, and being connected there with the tendon of the ext. brev. (Gruber, Koster, &c.). This anomalous slip of the ext. indicis has, in its turn, some claim to be considered the homologue of the ext. brev. hallucis.

I have considered the assumed homology between the short extensors of the thumb and great toe at some length, as it is very instructive. Similar reasoning could be applied in several other cases of assumed homology to show that they are to a large extent artificial.

(c) Provided there is no concomitant deficiency in the normal musculature, there is a good deal to be said in favour of an ext. brev. dig. manus being regarded as a derivative of the dorsal interosseous musculature. The chief evidence in favour of such an hypothesis is derived from (1) the fascial relationships, and (2) the nerve supply of the muscular slips which I have described in the earlier part of this paper.

(1) From the fascial relationships of these muscle slips it appears as though the m. inteross. dors. have a tendency towards overgrowth at the distal ends of the inter-metacarpal spaces where the covering fascia is of a loose nature and offers the least resistance to such an extension. In its most rudimentary condition, this overgrowth takes the form of a small fasciculus seeking attachment to the deep aspect of the supra-metacarpal fascia. In a more advanced condition, such an overgrowth extends proximally, creeping, as it were, in the interval of separation, between the interosseous and supra-metacarpal fasciæ, and eventually may invade the base of the metacarpus and dorsal aspect of the carpus, where, owing to the deep adherence

of the supra-metacarpal fascia, it finds a bony attachment. In other words, the direction of growth of these slips seems to be largely determined by the disposition of the supra-metacarpal fascia. In suggesting such a method of development for these slips, I know I am treading on very dangerous ground, as fasciæ are for the most part the creatures of the muscles, their disposition to be accounted for by muscular pressure and tension. The converse may, however, hold good to some extent, and fascial disposition may be one determining factor in muscular adaptation. In this case the close adherence of the interosseous fascia to the metacarpal bones, forming as it were the dorsal limit to the *m. inteross. dors.*, the loose nature of the fatty pads interposed between the knuckles, and the general disposition of the supra-metacarpal fascia, are certainly suggestive. These slips may possibly be the result of a delamination involving the *m. inteross. dors.*, followed by a secondary extension on to the carpus; and against such an explanation I could not urge any very strenuous argument. In whatever way these slips may be derived, it is obvious that if the process affects more than one *m. inteross. dors.*, the resultant will be a more or less complete *ext. brev. dig. manus*. What useful functions these slips in their rudimentary condition subserve, or what physiological necessity has invoked the tendency for a new extensor muscle to make its appearance on the back of the hand, requires investigation.

(2) The nerve supply of the muscle slips which I have described is very suggestive of their origin, and leaves but little doubt upon the matter. Unfortunately, little or no attention has been paid to the nerve supply of the muscles described by Wood, Macalister, &c. as *extens. brev. dig. manus*, and it is apparently taken for granted that such muscles are supplied by the *post. inteross. nerve*. An *ext. brev. dig. manus* derived in the manner I have suggested would, through the disposition of the supra-metacarpal fascia, find attachment to the dorsal aspect of the carpus, and overlies the final distribution of the *post. inteross. nerve*, the territory of which nerve it would consequently invade. Under these circumstances, a supply from the *post. inteross. nerve* would not be a matter of surprise. If it can be proved that a fully developed *ext. brev. dig. manus* is ex-

clusively supplied by the post. inteross. nerve, I admit that it would be practically conclusive evidence of the derivation of the muscle from the extensor sheet; but if, as it is quite possible, the muscle had a double nerve supply from the post. interosseous and ulnar nerves, such a condition would not necessarily put my hypothesis out of court.

Limb muscles with a double or variable nerve supply have been the subject of some controversy. Cunningham, who has devoted considerable attention to these muscles, is of the opinion that the nerve supply is of the greatest value in determining the morphological significance of a muscle; yet it cannot be regarded as an infallible guide. Paterson, who strongly advocates the exclusive distribution of the flexor and extensor nerves to the primitive ventral and dorsal sheets, accepts as the explanation of the nerve supplies of such muscles as the pectineus, biceps cruris, &c., the supposition that these muscles are the results of secondary fusions between primary segmentations; or, in other words, that they are compound muscles resulting from the fusion of dorsal and ventral elements.

Admitting that secondary fusion is in many cases the true interpretation of a double nerve supply, yet there are some cases to which it cannot obviously be applied, *e.g.* to the m. inteross. dors. of the foot muscles, which frequently receive their supply from both plantar and ant-tibial nerves. There is a certain amount of evidence to show that the boundaries of the muscular field of supply of an nerve are not strictly limited; *e.g.*, in the case of the plantar nerves, where apparently one plantar nerve tends to invade the territory of the other. Conversely, if a muscle primarily belonging to one field tends to invade an adjoining field, it is conceivable that such a muscle will attract a supply from the nerve of the field of invasion.

(*d*) If an ext. brev. dig. manus cannot be regarded as an atavistic anomaly, or as a derivative from any existing musculature, the only way in which its presence can be accounted for is to suppose that it is of entirely new origin—the product of a new muscle germ. Such an explanation is, of course, the last resort, and all other possible derivations must be disproved before it can be accepted.

The Pseudo-ganglion on the Post. Interosseous Nerve.

In tracing the terminal branches of the post. interosseous nerve I met with one case in which the pseudo-ganglion was very much smaller than is usually the case, and was continued into a trunk which crossed the space between metacarpals II and III, and was finally distributed to the skin covering the adjoining sides of the indicial and medial digits. This variation is worthy of note, as it has only been twice recorded, by W. Turner and Schwalbe.

ON CERTAIN POINTS IN THE ANATOMY AND MECHANISM OF THE WRIST-JOINT REVIEWED IN THE LIGHT OF A SERIES OF RÖNTGEN RAY PHOTOGRAPHS OF THE LIVING HAND. By T. H. BRYCE, M.B., *Lecturer on Anatomy, Queen Margaret College, University of Glasgow.*

(Communicated to the Anatomical Society, July 6, 1896.)

So far as I know, there has as yet been no account published of an attempt to apply the method of the 'New Photography' to the study of the articulations in the living subject. The present paper is an effort in this direction. It is obvious that the case of the wrist-joint is a favourable one for the application of such a method; but even here, we are limited to the study of the relative positions of the carpal bones in certain attitudes of the joint, as we cannot obtain the photo-shadows except when the hand is in the same plane as the forearm.

The photographs were taken from my own hand by Dr John Macintyre, of Glasgow, who very kindly put his valuable time, and unique skill in the technique, at my disposal for the purposes of the inquiry. They present the hand in the straight position—the axis of the hand in a line with the axis of the forearm—in radial, and in ulnar flexion. In the negatives, the impression on the plate being a shadow is really a positive, so that the prints are negative pictures, and the right hand appears as the left. The periosteum, the articular cartilages, and the triangular fibro-cartilage do not appear; and the shadows of the carpus being life size, if we allowed for the thickness of the soft structures, the actual spaces between the bones might be measured. The bones, however, appear on the same plane, so that an error would be introduced, and I have made no attempt to express any of the relationships in figures. Any measurements I do give must be understood as applying only to the photographs.

Photograph i. shows the hand with its axis in a straight line

↓.
Right hand. Supine in straight position.

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with that of the forearm, and in the supine position; Photograph ii., the hand in the same attitude in the prone position.

A general survey of these photographs shows at once that there is a degree of 'incongruity' in the carpal articulations, not represented in our text-books, nor allowed for in our articulated skeletons of the hand.

Before analysing the relationships of the carpal bones to the bones of the forearm and to one another, as seen in the photographs, I may call attention to the demonstration they give of the lateral thrust of the ulna in pronation. The centre of the shadow of the styloid process of that bone is, in the supine position, 12 mm. removed from the central point of the transverse axis of the wrist, while in pronation the distance is increased to 25 mm.

Further, in comparing these two photographs with Photograph iii., representing the hand in pronation in the position of rest, it is to be noticed that in pronation there is slight amount of adduction of the hand, which is rectified in No. ii. by carrying the hand to the radial side until its axis, passing through the third metacarpal bone, is in a straight line with the axis of the forearm. I have not adopted Meyer's¹ 'middle position,' in which the hand stands somewhat adducted, because there is no fixed axis from which to work.

(1) *Relations of the Carpal Bones to one another, and to the Radius and triangular fibro-cartilage, in the straight position.*
(Photographs i., ii., and iii.)

Proximal range.—The scaphoid lies very obliquely to its radial facet in the palmar view,—its long axis being directed nearly straight downwards and forwards. It grasps the os magnum, as seen by the overlapping shadow. In the dorsal view the obliquity is less marked, due to the shape of its radial articular surface. Almost the whole of this surface is in play with the radius. There is an angular interval between it and the lunar, only the inferior parts of the contiguous surfaces touching one another; in the dorsal view the inferior extremity of the bone

¹ Cf. Meyer, *Die Statik und Mechanik des Menschlichen Knochengerüsts*, 1873.

is released from the os magnum, and the greater part of the articular surface, for the trapezium and the trapezoid, is out of play with these bones.

The lunar overlaps the situation of the triangular fibro-cartilage to a considerable extent. The text-book figures vary in respect of this point, some showing the bone confined to its radial facet, some showing a greater or less degree of overlapping. The photographs confirm the statement that the lunar corresponds to the radial facet and the triangular fibro-cartilage.¹ It plays in the straight position with the entire surface of the cartilage, and the greater part of its superior articular surface is in contact.

The pyramidal is far removed from the situation of the fibro-cartilage; it lies to its ulnar side, and must play in the angular interval between the ligamentous bands passing from the ulna to its anterior, internal, and posterior aspects.

Distal range.—The trapezium and trapezoid, which throughout we shall consider as one entity, play only with the distal part of the surface on the scaphoid. The trapezoid, in the dorsal view, is in less close contact with the scaphoid than the trapezium. The long axis of the os magnum coincides with the long axis of the hand when it is placed strictly in the straight position. The long axis of the unciform is also parallel to the axis of the hand. Its tip fails to reach the lunar, and there is an angular interval between it and the pyramidal—the whole opposing concavo-convex facets being out of play.

Meyer² describes an 'incongruity' at the ulnar side of the intercarpal joint, corresponding closely to that seen in Photograph iii., the whole dorsal and ulnar part of the facet on the unciform being out of touch with the pyramidal; but the figure differs from his description in the fact, that even in it the unciform does not touch the lunar.

Coming to the interpretation of the photographs above described, it is evident that there is a degree of laxity in the intercarpal articulation which is not allowed for in any of the descriptions of the mechanism of the wrist-joint. These all proceed on the assumption that the carpal ranges are locked or jammed together.

¹ Cf. Shepherd, *Jour. Anat. and Phys.*, vol. xxv.

² Meyer, *loc. cit.*

Figure A is a photograph of a preparation in which the anterior and lateral ligaments have been left intact, while the posterior ligaments have been removed to show the articulation.

A.—Straight Position.

The attitude *naturally* assumed by the ranges, when not *artificially* jammed, is demonstrated; and when compared with the Röntgen Ray photograph, I think it must be admitted that the ranges during life *are released* from one another—in a manner not represented in the traditional figures. The proximal range is in a position of greater extension than has been represented. The trapezium and trapezoid play only with the distal part of their facets on the scaphoid, and the unciform does not in this position touch the lunar.

The relations of the unciform and pyramidal require special notice.

Figures E and F show the opposing surfaces of the two ranges. The articular surface on the pyramidal for the unciform is, in well-marked recent specimens, crossed obliquely by a distinct ridge running from the dorsal end of the luno-pyramidal articulation forwards and inwards to the palmar border. This ridge

divides the surface into two parts, a *radial and palmar*, triangular and concave, with its base at the lunar border and its apex at the junction of the ridge and the palmar border; and a *dorsal*

E.—The Proximal Carpal Range from its Inferior Surface.

and ulnar, which presents a concavity at its dorsal end and a convexity at its palmar. The apex of the unciform rises highest on the palmar aspect, forming a smooth, rounded convexity. From this, running backwards to the dorsal border, is the narrow

F.—The Distal Carpal Range from its Superior Aspect.

lunar surface, altogether out of play in this position. The remainder of the articular surface may be divided into two parts, a *radial and palmar*, triangular and convex, corresponding

to the side of the tip of the bone, and a *dorsal and ulnar*, convex dorsally, and concave at its palmar end.

In the straight position, the triangular convex part of the apex of the unciform alone plays with the pyramidal, gliding on the triangular and concave area above described; the whole dorsal and ulnar concavo-convex facets are out of play.

It may also here be noted that the obliquely directed surface on the side of the head of the os magnum for the scaphoid is out of play in the straight position.

(2) *Relations of the Bones in abduction.* (Photograph iv.)

Proximal range.—There is very little change in the position of the lunar and pyramidal. The distance between the edge of

B.—Radial Flexion.

the lunar and the styloid process is diminished by only 1 millimetre. There is no evidence of any distinct degree of flexion of the bones. With the scaphoid it is otherwise. There has evidently taken place a rotation on its transverse axis, so that its shadow is shortened, and it grasps the os magnum more closely.

Distal range.—The relative positions of the shadows of the

bones are more modified. The angular interval between the unciform and pyramidal is increased; the apex of the unciform has apparently glided down the ulnar plane of the socket.

While the lunar has remained stationary, the os magnum now lies obliquely, as if it had rotated on a point in its neck, so that the head is carried towards the ulnar side, till its ulnar edge projects beyond the edge of the lunar, and seems to touch the angle of the pyramidal. The socket for the head of the os magnum is confined to the lunar. The length of the shadow of the os magnum is unchanged. The trapezium and trapezoid have shifted towards the radial side, until the trapezium appears close to the styloid process of the radius.

Figure B shows the same preparation as in figure A in abduction, and interprets the 'shadowgram.' The marked flexion of the scaphoid is demonstrated, and the trapezium and trapezoid have glided into full contact with it. The lateral movement of the head of the os magnum is shown. There is slight compensatory flexion of the lunar and pyramidal—due to the preparation being fixed flat to the board—which is not seen in the Röntgen Ray photographs.

(3) *Relations of the Bones in adduction.* (Photographs iii. and v.)

Proximal range.—There is now considerable lateral displacement. The lunar has receded on to its radial facet; the pyramidal has ascended on to the fibro-cartilage. The scaphoid is carried towards the radial side until it projects considerably beyond the styloid process. The pyramidal, while it has thus glided, shows no evidence of any degree of extension, nor does the lunar. The scaphoid is extended to its utmost extent on the lunar, so that its shadow is elongated. Its distal end is freed from the os magnum; the luno-scaphoid articulation is now in complete contact.

Distal range.—Again there is evidence of a greater degree of readjustment. The os magnum is rotated so that its head is carried towards the radial side, and its shadow remains of exactly the same length. The head now lies to a considerable extent off the lunar, the scaphoid forms the major part of its

socket. Following this movement, the unciform has become oblique, and has ascended into full contact with the pyramidal. The apex now plays on the lunar. The trapezium and trapezoid are carried away from the scaphoid. Figure iii. shows the earliest stage of adduction: the unciform and pyramidal are coming in contact, and the proximal range is beginning its excursion towards the radial side.

The metacarpal range does not show evidence of any movement on the distal carpal range in any of the lateral positions.

C.—Ulnar Flexion.

Figure C shows the preparation now in the position of adduction. The extension of the scaphoid is demonstrated, and the displacement of the proximal row. The head of the os magnum has been subjected to a lateral movement and a slight pivoting, as seen by the narrowed facet on the radial side of the head of the os magnum. The apparent extension of the lunar and pyramidal is also to be noted, but this is a point which will require special notice hereafter.

The interpretation of the appearances presented by this series of photographs is somewhat difficult. The effect of movements of the two ranges seen on the plane may be misleading, and

therefore they can only serve as a guide to the renewed study of the movements seen in a preparation.

It is quite clear at the outset, as already said, that there is revealed a greater degree of laxity of the articulations during life than has been usually supposed, especially at the ulnar side. The ranges in the position I have termed the 'straight position' are released from one another by the proximal range being in a position of greater extension than usually depicted. The assumption of the 'locking' of the ranges has led to the acceptance of such a statement, as made by Humphry.¹ "The alternating concavo-convex facets of the two rows are so adapted to one another as to prevent all movements besides flexion and extension." Henle² described the intercarpal joint as a section of a large imaginary enarthrodial joint, the socket of which was possessed of a process received into a hollow of the head. To the original rotatory would thus be added movements of flexion and extension. Meyer³ described a rotatory movement of the scaphoid round the os magnum, coming into play in extension; but he confined the lateral movements to the radio-carpal joint thus—to take ulnar flexion as an example; there are three kinds of ulnar flexion—dorso-ulnar, volar-ulnar, and pure ulnar flexion. In dorso-ulnar there is extension of the unciform on the luno-pyramidal element of the proximal range, associated with extension of this, the meniscus—as he calls it—at the radio-carpal joint. Volar-ulnar flexion is the result of a movement of flexion in both joints, associated with a lateral displacement of the meniscus towards the radial side; while pure ulnar flexion is a combination of these two, the flexion in the intercarpal being compensated by an extension in the radio-carpal joint, so that only the lateral movement is brought about. It is brought to a close by the contact of the pisiform and the head of the ulna. This, the photographs show, is certainly not the case. Much the same kind of mechanism he attributes to the movement of abduction, but he does not describe in either case the play of the elements on the opposite side of the carpus from which the movement is taking place.

¹ Humphry, *The Human Skeleton*.

² Henle, *Bänderlehre*.

³ Meyer, *loc. cit.*

III.
Right hand. Prone slightly adducted.

Henke's¹ views have received wide assent, and are adopted by Luschka and Gegenbaur among others. His two axes are, however, admittedly artificial: the axis of the proximal range does not take account of the screw movement described later by Meyer, nor is the axis of the articulation between the pyramidal and the unciform parallel with that of the joint between the scaphoid and trapezium and trapezoid.

He describes the movement between the unciform and pyramidal as a rocking, the joint serving principally to limit the extreme movements by the anterior and posterior borders coming into contact with the corresponding borders of the pyramidal. Further, "by the movement of the 1st range, there is the possibility of a displacement of the unciform out of the hollow of the pyramidal outwards and inwards, so that in flexion of the proximal range, and also in extension of the distal, the lunar border of the unciform is separated from that bone." Meyer also describes this gliding between the bones by the displacement of the meniscus in extension. Both observers started with the assumption that the unciform was in contact with the lunar in the straight position, and the separation of the bones thus described cannot, I believe, wholly correspond either in kind or degree to that seen in the photographs.

Now, if the rows are 'jammed' together, this rotation round two axes crossing in the os magnum can readily be demonstrated, but the main axes are combinations of several axes which do not coincide with one another. If, however, the ranges are released as the photographs show they are in living hand, it is impossible to regard the matter so simply. The positions shown in the photographs, especially when the minute movements of the proximal range in respect of flexion or extension are borne in mind, cannot be produced in a preparation by an adjustment of the ranges rotating in two simple axes. Nor does such a simplification of the mechanism of the joint account for its anatomical structure. The desideratum is, such an interpretation of the mechanism of the intercarpal joint as will justify its fundamental structure, which could not be better described than it was by Henle, as mentioned above.

The study of preparations of the wrist-joint in the light of

¹ Henke, *Anatomie und Mechanik der Gelenke*, 1863.

this series of photographs leads then, I believe, to some modifications of the account usually given of the wrist-joint.

1st. In regard to the radio-carpal joint.—The proximal range is more extended than usually represented. The lunar in the straight position corresponds to the radial facet and the triangular fibro-cartilage, which together form a triangular socket for its triangular superior surface. Extension of the range is a small movement, and is associated with a displacement towards the radial side and a screw movement of the lunar, as described by Meyer.¹ The result is, that the scaphoid is carried towards the palmar aspect, and the pyramidal towards the dorsal, till it plays on the fibro-cartilage. In adduction, the lateral displacement and screw movement are carried out, only with a still less degree of extension than in pure extension. The semilune for the head of the os magnum thus does not move in a simple transverse axis, but is so rotated that it looks more directly downwards than it does in the straight position.²

Flexion of the range is a more extensive movement; and it is associated, as the return from full extension is initiated, by a displacement towards the ulnar side, with an undoing of the screw movement. The scaphoid comes to lie nearer the dorsal aspect, and the pyramidal is carried more towards the palm. The range is, by means of this mechanism, adjusted to certain movements of the second range, much in the manner of a meniscus, as Meyer¹ put it, though he did not describe its relation to the lateral movements of the joint.

Besides these points, there is the already mentioned rotation of the scaphoid on the lunar. This is possible owing to the laxity of the scapho-lunar interosseous ligament, which is sometimes absent, and also to the weakness of the palmar ligament. The dorsal, on the other hand, is a strong band; and I have in some cases observed it passing in between the bones to form a dorsal interosseous ligament. The bones are bound firmly at their dorsal ends in such a way that free rotation towards the palm is allowed, but the movement is checked by the dorsal ligament, when it is attempted to extend the scaphoid beyond the position in which its long axis stands in a line with the radius.

¹ *Loc. cit.*

² *Cf. Photographs iii. and v.*

v.
Right hand. Prone in adduction.

There is also a movement of the pyramidal on the lunar, by which it is carried on its triangular surface downwards, but there is only slight rotation. It comes into play in abduction.

2nd. The intercarpal joint.—The alternating concavo-convex facets are not adapted closely to one another, when the axis of the hand is in a line with the forearm, and the hand lies in the same plane as the forearm. Besides the ulnar ‘incongruity,’ we must again refer to the incomplete contact, between the trapezium and trapezoid and the scaphoid, and also to the manner in which the latter grasps the os magnum, although there is not accurate contact in the ‘straight position’ between the two.

If the inferior aspect of the proximal range be examined, (fig. E), besides the character of the articular surface on the pyramidal, it is to be noticed that the borders of the semilune of the lunar are practically parallel, that the dorsal and palmar borders lie oblique to them, and that the curvature is not identical throughout. The dorsal and radial part is less steep.

The ‘socket’ formed by the scaphoid, lunar, and the triangular concave portion of the articular surface of the pyramidal presents an antero-posterior and a transverse concavity, the axes of which are at right angles to one another.

The ‘head’ is formed by the os magnum and the tip of the unciform and triangular convex surface on its ulnar side. It is rounded in every direction. The borders of the semilunar convexity on the head of the os magnum are not parallel;¹ and further, the breadth of this convexity corresponds to the breadth of the semilune in which it plays only at its dorsal end, while anteriorly it is considerably broader, and overlaps the furrow for the unciform on the one hand, and the scaphoid on the other. The dorsal part, and the oblique surface for the scaphoid, are not in play in the straight position. Further, the long axes of the facets on the scaphoid for the trapezium and trapezoid are nearly, though not quite, parallel to the long axis of the transverse concavity.

The ‘head,’ as far as the surfaces are concerned, may be described as capable of moving freely round the axis of the

¹ The carpal bones are subject to some variation in respect of these points; but in a carpus with well developed bones, such as the one from which the illustrations have been taken, the conditions are, generally, as I have described.

antero-posterior concavity, less freely round the axis of the transverse concavity, and of some degree of rotation round its longitudinal axis.

The only part of the intercarpal joint in which the surfaces are in close contact is the articulation between the head of the os magnum and lunar. The second range, with the hand, moves round the axis of this articulation—in an oblique plane—from the radial to the ulnar side. In extension from the middle position, the hand would be carried towards the ulnar side, were it not that, owing to the difference in curvature described above, a rotation of the 'head' takes place. This brings the unciform into contact with the lunar, and the whole range into a more strictly transverse axis. The dorsal border of the unciform, gliding down on the pyramidal, tends further to increase the rotation. Meantime, extension of the proximal range has set in, with its radial displacement and screw movement, so that the hand is brought into the strictly transverse axis, while the 'meniscus' is kept accurately applied to the second range. Movement has now ceased at the ulnar side; but owing to the rotation of the 'head,' the trapezium and trapezoid are prevented from coming into complete play with the scaphoid. Some movement is therefore still possible at the radial side; the trapezium and trapezoid glide into complete contact with the scaphoid, the rotation is undone, and the hand stands in strained extension, slightly in the abducted position.

In flexion from the middle position, on the other hand, there would be a movement towards the radial side; but as flexion proceeds, and the os magnum comes in contact with the embracing point of the scaphoid, the whole range is displaced to the ulnar side—till the unciform and pyramidal come into contact—by the necessary rotation of the os magnum on its longitudinal axis. Thus the hand in extreme flexion is somewhat adducted, so that, in the movement from extreme extension to extreme flexion, it is carried in an oblique plane round a transverse axis from the radial to the ulnar side, which is also directed backwards—in short, round an axis closely corresponding to Henke's. But in the joint itself this movement is not one round a simple axis in that line. It is a movement round the axis of the lunar

semilune, directed from the radial to the ulnar side and forwards, associated with rotation of the head.

With regard to the lateral movements, they take place round the axis of the transverse concavity. This movement is manifestly possible from the straight position towards the ulnar side. The trapezium and trapezoid are carried off the scaphoid, the unciform glides on the pyramidal till its apex comes in contact with the lunar, and the palmar and ulnar concavity engages with the corresponding convexity on the pyramidal. So far there is no rotation, or at least very little rotation, of the 'head.' But in complete adduction there is an extension of the unciform on the pyramidal, and a rotation of the 'head.' Meantime, the proximal range is displaced to the radial side, and undergoes its screwing movement, so that the semilune is kept in the same relation to the head of the os magnum. In radial flexion, the lateral movement of the os magnum would be impossible, but for the flexion of the scaphoid on the lunar. The effect of this is to carry away the facets for the trapezium and trapezoid from these bones, to make the scaphoid grasp the os magnum more closely, to displace its tip towards the palm, and bring its curvature for the side of the os magnum, more into the antero-posterior axis. Thus the os magnum is so far released from the scaphoid, and rotates on its oblique antero-posterior axis in such a manner as to carry the tip of the unciform further away from the lunar, the trapezium and trapezoid over their facets on the scaphoid.

When the movement is attempted in the plane of the forearm, it is very limited, for the long axes of the facets on the scaphoid are not exactly parallel with the direction of the displacement; but if abduction be continued, rotation round the longitudinal axis of the 'head' takes place, the trapezium and trapezoid glide into complete contact with the scaphoid. There is, in fact, extension of these bones on the flexed scaphoid. In the proximal range there is little movement,—only a further undoing of the screw action,—so that the semilune is kept adjusted to the rotated head of the os magnum.

Thus abduction is partially as Henke described—an extension of the second, and a flexion of the first range; but at the same time there is, owing to the movement round the antero-posterior

axis and the rotation of the head, a movement towards the palm or flexion at the ulnar side, just as in ulnar flexion there is extension at the ulnar side, and flexion at the radial side of the articulation.

If the hand be carried from extreme abduction (really dorso-radial flexion) to extreme adduction (really dorso-ulnar flexion), this alternate flexion and extension of the borders of the hand can be readily demonstrated. Within certain limits all degrees of flexion and extension may be combined with the lateral movements. In complete flexion, lateral movements cannot be spontaneously initiated, because the trapezium and trapezoid are locked on the scaphoid, and the anterior border of the unciform on that of the pyramidal; but they can be produced by the application of external force, owing to the laxness of the whole articulation in this position.

In complete extension they cannot be initiated, either spontaneously or by force, owing to the complete locking of the whole articulation.

Further, if the adducted hand be extended, it passes into the position of pure extension. This is due to the undoing of the rotation of the 'head,' and to extension proceeding at the radial side until the adduction is entirely rectified. If the fully abducted hand be flexed on the other hand, it passes into the position of pure flexion because of the undoing of the lateral movement and rotation of the 'head,' as the os magnum engages with the scaphoid as already described.

Thus, starting from the position that during life the carpal ranges are released from one another, the interpretation of the movements of the carpal ranges in the light of this series of photographs, gives a fairly complete and simple picture of its mechanism, which is strictly in keeping with the peculiarities of its structure, and is consistent with Henle's¹ description of the fundamental character of the intercarpal joint.

Henle described abduction as taking place in the intercarpal, adduction in the radio-carpal joint; and this is quite true if we start from the 'middle position' of Meyer, in which the unciform is in contact with the pyramidal. (Photograph iii.)

Much of the above description has been a reiteration of old

¹ Henle, *loc. cit.*

facts in a new light; but it provides, I believe, a picture of the mechanism of the joint more in keeping with the anatomical relations of its elements, and I am not aware that the possibility of a lateral movement of the head of the os magnum has been before described.

Still further, in accepting such an account of the mechanism of the joint, we have also an explanation of certain points in the arrangement of both ligaments and muscles.

The ligaments of the radio-carpal and intercarpal joints are lax, and allow of very free play of the ranges. We have seen that the lunar and pyramidal do not change their relative positions, and they undergo less displacement than any of the other bones except the os magnum. Hence, most of the stronger bands in both dorsal and palmar radio-carpal ligaments pass to these bones, some fibres passing on to the os magnum. Moreover, the former pair in adduction, and in extension, pass towards the radial side; hence the fibres are mostly oblique from the radius to the pyramidal. It is also striking that on both dorsal and palmar aspects the intercarpal ligaments converge on the neck of the os magnum, the palmar series receiving the name of the 'ligamentum radiatum.'

This is quite in keeping with the view that there is a rotation in all directions of the head of the os magnum, and is an unintelligible arrangement if only flexion and extension be allowed.

The extensor muscles of the wrist, from their relations and attachments, are certainly more efficient than the flexors in producing lateral movements. The flexor carpi radialis, from its oblique position, is much more of a pure flexor than an abductor; while the flexor carpi ulnaris can only have an indirect action on the distal range, and will be effectual chiefly in producing the radial displacement of the proximal range.

In the attachments and relations of the tendons of the extensors, on the other hand, we have just the muscular mechanism, which would contribute to the kind of rotation of the hand with the distal range, on the 'head' formed by the os magnum and tip of the unciform, in the socket of the first range, which has been attributed above to the intercarpal joint.

THE 'FORNIX SUPERIOR.' By G. ELLIOT SMITH, M.D.,
Ch.M. (Sydney), ('James King' Research Scholar of the
University of Sydney).

THE knowledge that the septum pellucidum contains nerve fibres within its tissues is as old as the science of histology itself. But although an almost continuous succession of histologists, from Malpighi onwards, have recorded the existence of such fibres, it has been reserved for anatomists of our own time to afford the first accurate information concerning the disposition of these 'septal' fibres.

One important record, however, of the existence of these fibres, which was made in 1845 by Arnold in his *Handbuch der Anatomie des Menschen*, appears to have been entirely overlooked by his immediate successors. He called the 'fornix,' '*fornix internus*,' in order to distinguish it from the 'cingulum'—his '*fornix periphericus*';—and stated that these two series of association-fibres were connected with one another by means of numerous fibres *perforating the corpus callosum*.

Within comparatively recent times Meynert, Huguenin, and Ganser have again called attention to the fact that certain fibres break through (*durchbrechen*) the corpus callosum from above, in order to reach the septum pellucidum.

It is, however, to the comparative method that we are indebted for the first accurate knowledge of these septal fibres, and to Stieda belongs the signal merit of giving the first description. In 1869, Stieda described a bundle of nerve fibres lying on each side of the mesial plane in the septum pellucidum, between the corpus callosum and psalterium, of the mouse. In the clear figures which illustrate his memoir, he calls these fibres '*Marksubstanz des Cornu Ammonis*.'

In his investigations concerning the structure of the brain of a number of lowly organised mammals in 1872, Forel found this well defined strand of longitudinal fibres in the septum, which Stieda had described three years previously, and called it the '*fornix longus*.' He introduced this name in order to dis-

tinguish the longitudinal from the commissural fibres of the fornix, which he called '*fornix transversus*.' It will thus be observed that Forel intended the term '*fornix longus*' to apply to *all the longitudinal uncrossed fibres of the fornix*, and not to any special group of such fibres.

Both Forel and Stieda regarded these septal fibres as projection fibres of the Ammonshorn.

Ganser, in his monograph on the brain of the mole, describes the *fornix longus* (which he calls '*fasciculus arcuatus septi pellucidi*') arising from the gyrus fornicatus, and breaking through the corpus callosum to become lost in the septum. Meynert and Huguenin describe a connection between the fornix and the white substance of the gyrus fornicatus by means of fibres, which pass more or less vertically between the fibres of (*i.e.* through the substance of) the corpus callosum.

In the *Philosophical Transactions* for 1891, Beevor says (p. 182) that some of the fornix fibres (in *Hapale*), on being traced backwards, are found to—

"pass above [the inferior recurved tip of the splenium] and enter into the posterior part of the corpus callosum, where they have a direction at right angles to its transversely cut fibres, and thus separate off the splenium from the main body of the corpus callosum The individual [perforating] fibres of the fornix can be traced as far as the superior surface of the posterior part of this structure [corpus callosum], but what their ending may be cannot be ascertained. They do not seem to be continuous with the cingulum, as has been described by Huguenin [and Meynert]."

In March 1895, Oskar Vogt published an important memoir ("Ueber Fasersysteme in den mittleren und caudalen Balkenabschnitten," *Neurologisches Centralblatt*, No. 5), in which he inclines to the view that fibres derived from the striæ mediales Lancisii break through the corpus callosum, to contribute towards the formation of the *fornix longus*.

In a paper published in the *Verhandlungen der anatomischen Gesellschaft* in 1894, Koelliker described the *fornix longus* in the rabbit as "a median paired longitudinal fibre mass which arises from the white matter of the gyrus fornicatus, and the 'lamina superficialis cornu Ammonis' [alveus], breaks through the corpus callosum and terminates in the septum pellucidum and columns of the fornix." And in the second half of the second volume

of his *Handbuch der Gewebelehre des Menschen*, published in the summer of this year, he gives expression to similar views, and suggests the less ambiguous name '*fornix superior*' for the fibre tract under consideration.

The Fornix of the Ox.

The '*fornix superior*' may be readily demonstrated in (probably) any mammalian brain. It is more difficult to find in the brain of man and microsmatic mammals generally, for the simple reason that the proportion of 'callosal' fibres to fornix fibres is so overwhelming. But in most mammals it is singularly easy to find, and may be readily demonstrated. Thus it is easily exposed in sagittal sections of the cerebrum of any of the 'domestic animals.'

Its minute anatomy is best studied in sagittal sections of the forebrain of such small mammals as the mouse, rat, rabbit, kitten. I have obtained a very fine demonstration of the fibre tract in the flying fox (*Pteropus poliocephalus*).

It is best displayed by the Weigert stain, or some modification of it. (Kultschitzky's method has been found to yield very good results.)

In large macrosmatic brains, such as that of the ox, the main facts concerning the *fornix longus* may be readily demonstrated to the naked eye in a mesial sagittal section of a cerebrum (preferably one that has been hardened in some chromium-salt).

In figure 1 such a section is represented twice the natural size, the nerve fibres being shown as they are seen in sections magnified with a Zeiss D objective. The outlines of the fimbria and fascia dentata are indicated as they are seen in perspective in a view of the mesial aspect of the separated hemisphere.

The fascia dentata (*F.D*) is bounded posteriorly by the hippocampal fissure (*f.h*), and presents two distinct flexures. Its inferior extremity curves forwards with a large sweep, and at the same time tapers to form the narrow grey band (*b.G*), whose homologue in the human brain is the '*bandelette de l'uncus*,' or the '*band of Giacomini*.' Dorsally, the fascia dentata becomes very closely applied to the ventral aspect of the great dorsal commissure, where it undergoes a very sudden

bending (*flx*), and curves around the ventral aspect of the splenium (*spl*), at the same time tapering to form the fasciola



FIG. 1.—Brain of Ox.

cinerea (*fasc*). The hippocampus (of which the fascia dentata forms part) undergoes a corresponding infra-splenic bending,

fp

J

FIG. 2.—Scheme of Fibres in Ox.

which may be distinguished as the 'hippocampal flexure.' The hippocampus, being bulged into the descending horn of the

lateral ventricle, is not (apart from the fascia dentata) visible upon the surface of the brain. For convenience of description, the hippocampus may be divided into two parts:—(i.) the hippocampal flexure, and (ii.) the rest of the hippocampus, which may be called the ‘ventral limb.’ The latter in all higher mammals constitutes almost the whole of the hippocampus. The hippocampus, however, does not stop at the splenium, but is continued on to the dorsum of the corpus callosum as a thin degenerate grey covering (*induseum*), which contains the striæ longitudinales. This grey covering represents the hippocampus (*not the fascia dentata only*, as writers generally assert), which has degenerated as a result of the enormous stretching to which it has been subjected by the elongation of the dorsal commissure (corpus callosum). (iii.) This thin grey band forms a third hippocampal segment, and may be called the ‘dorsal limb.’

The Fornix Fibres.

The fibres which cover the ventricular surface of the ‘ventral limb’ of the hippocampus collect to form a very prominent white band—the fimbria (*Fi*)—which is placed in front of the fascia dentata. These fibres arch round to the postero-inferior border of ‘septum pellucidum’ (*sept*), which they all enter. A considerable portion of these fibres of the fimbria assume a transverse direction as soon as they reach the ‘septum,’ and form the main bulk of the psalterium (*ps'*). The other (non-crossing) fimbria fibres pass forwards in the septum *between the transverse fibres*, and arch forwards and downwards (*f.l*) immediately in front of the latter (*ps'*). Thus the longitudinal fornix fibres derived from the fimbria (or posterior pillars of fornix) break through (*i.e.*, pass between the fibres of) the psalterium to reach the septum pellucidum.

The fibres which are connected with (*i.e.*, form the alveus of) the ‘hippocampal flexure’ (*flx*) may be divided (like the fibres derived from the fimbria) into commissural and longitudinal groups. The transverse or commissural fibres in part form a narrow bridge (*ps''*) extending from the main bulk of the psalterium (*ps'*) to the ventral part of the splenium (*ps'''*). The rest of the commissural fibres derived from the infra-

splenic part of the hippocampus are mixed with numerous fibres of another origin (pallium) to form the ventral part of the splenium (*ps'''*). The longitudinal uncrossed fibres derived from the alveus of the hippocampal flexure extend upwards *between the commissural fibres derived from the corresponding parts of the hippocampus* to enter the narrow strip of grey matter (septum pellucidum) which fills up the gap between psalterium and corpus callosum. Here the longitudinal fibres assume a horizontal direction, but soon curve downwards in the septum and associate themselves with the longitudinal fibres derived from the fimbria to form one bundle of uncrossed fibres (*f.l*), which is the *fornix longus* in the sense of Forel.

By analogy, one might expect to find two series of fibres springing from the 'dorsal limb' of the hippocampus. But here the conditions are somewhat different. In the Marsupialia (fig. 3) and certain Cheiroptera (*Nyctophilus timoriensis*), the dorsal limb of the hippocampus (fig. 3, *c.A*) is not degenerated, and the arrangement of its 'fornix' fibres is analogous to that of the ventral limb. In other words, its uncrossed fibres (fig. 3 in the 'septum' [*sept*]) pass between the crossing fibres to enter the 'septum.' But in the higher Mammalia, the invasion of the dorsal limb of the fornix commissure (fig. 4, *ps^d*) by a rapidly increasing number of non-hippocampal fibres (*i.e.*, fibres from the pallium) complicates matters considerably. In the first place, the disproportion between the number of hippocampal and non-hippocampal fibres in the great commissure would render the recognition of the former practically impossible. Then, again, the great stretching and consequent atrophy of the 'dorsal limb' of the hippocampus of most Eutheria would further diminish, if it did not entirely abolish, the hippocampal factor in the corpus callosum proper (as far as commissural fibres are concerned). It is therefore impossible to say whether any hippocampal commissural fibres exist in the corpus callosum, apart from the splenium (and, of course, psalterium), where they can be demonstrated.

But the case of the uncrossed fibres is very different. It can be readily shown in sagittal sections that fibres springing from the *stria medialis Lancisii* (*s.m.L*) (which is the 'fimbria' of the 'dorsal hippocampus') pass more or less vertically from above

downwards between the transverse fibres of the corpus callosum to enter the septum. Fibres also spring from parts of the

so
p
cm
cf

FIG. 3.—*Perameles nasuta*. × 6.

degenerated dorsal hippocampus on the outer side of the stria medialis and behave in a similar manner. These 'perforating

fibres' (*f.p*) break through the corpus callosum from above, and in the septum associate themselves with the other longitudinal fibres of the fornix. In the region of the splenium these 'perforating fibres' are more numerous, for two reasons:—(1) because the hippocampus is not degenerated to the same extent that it is towards the 'genu'; and (2) because many fibres appear to extend from the hippocampal flexure around the splenium before they perforate the corpus callosum to join the *fornix superior* (*f.sup*).

The *fornix superior* therefore consists of those longitudinal

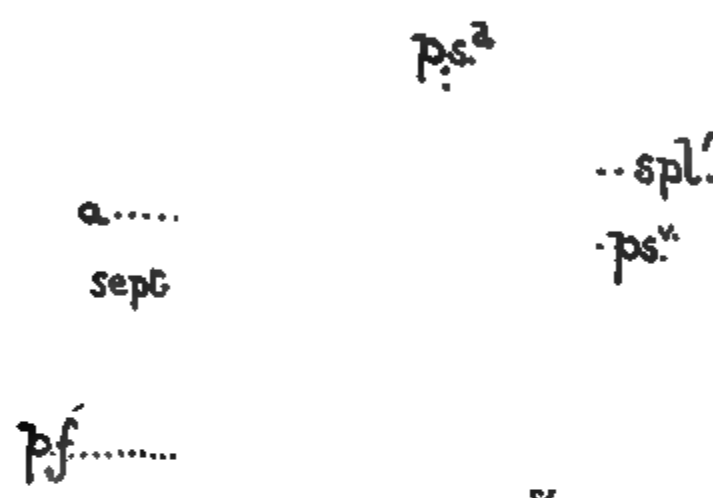


FIG. 4.—Scheme of Fibres in *Perameles*.

(i.e., uncrossed) fibres of the fornix which spring from the 'hippocampal flexure' and the 'dorsal limb of the hippocampus.'

All fornix fibres may be divided into two groups:—(1) commissural ('*fornix transversus*' of Forel), and (2) longitudinal ('*fornix longus*' of Forel).

In the higher mammals all the longitudinal fibres enter the septum pellucidum, where they may be divided into two (or perhaps three) groups.

(a) The largest group of fibres converges behind the *ventral* (so-called '*anterior*') *commissure* to form the *columna fornicis* (*c.f*).

(b) A considerable but more scattered strand of fibres passes in front of the ventral commissure. These are the *precommissural fibres* (*p.f*).

(c) There is probably a third series of fibres which arise or terminate in the 'septum' itself. But of this nothing definite

is known. But the 'septum' consists in most mammals of a large grey mass, which contains numerous polymorphous nerve cells, whose axis cylinder processes mingle with the fornix fibres.

From this account of the arrangement of fibres in the ox-brain, it is evident that *all the longitudinal uncrossed fibres of the fornix break through some part of the great dorsal commissure (psalterium, splenium, or corpus callosum, as that term is generally understood) in order to reach the septum.* These fibres constitute the true *fornix longus*. The *fornix superior* consists of those fibres of the *fornix longus* which do not pass through the main mass of the psalterium, but break through a commissure of non-hippocampal or a mixture of the latter and hippocampal fibres (*i.e.*, corpus callosum and its splenium).

A few fibres of the fornix do not pass through any commissure. In the marsupial (fig. 4a) these fibres spring directly from the most anterior part of the hippocampus, and pass downwards to their destinations in front of the commissures. The corresponding fibres in the higher mammal (fig. 2a) become pushed forward by the extending genu corporis callosi, but their essential disposition is unaltered, *i.e.*, they spring from the anterior extremity of the stria mesialis Lancisii.

The figures and schemes which accompany this paper are largely complementary to the written account, many details which are not referred to in the text being graphically represented in the illustrations.

Two widely separated types have been thus presented in order to bring into prominence the effects of (i.) a replacement of hippocampal by non-hippocampal (pallial) in the dorsal limb of the dorsal commissure (fig. 4, *ps^d*), and (ii.) the elongation of this structure owing to the rapid increase of the 'invading' fibres. The relation of the ventral limb of the fornix commissure (fig. 4, *ps^v*) to the 'septum' in the marsupial is, to all intents and purposes, identical with that of the main mass of the psalterium (*ps'*, figs. 1 and 2) in the higher mammal. But the rapid backward extension of the 'corpus callosum' is not accompanied by a corresponding extension of the psalterium, which therefore becomes greatly thinned at its junction (*ps''*) with the splenium (*ps'''*).

At the same time, in spite of all these differences of a

topographical nature, the general plan of arrangement of the fornix fibres remains unchanged in the transition from Meta- to Eu-theria, just as the former is identical in its general plan with the Prototherian and Sauropsidan types.

In fact, in one Eutherian order—the Cheiroptera—representatives of the two types (figs. 4 and 2) are found in *Pteropus* and others on the one hand, and in *Nyctophilus* on the other. In man the conditions differ only in degree from those of the ox. Thus the greater backward extension of the corpus callosum and the diminution in size—both relative and absolute—of the hippocampus and fornix combine to reduce the psalterium (fig. 5, *ps'* and *ps''*) to a very thin membrane of supporting tissue, containing only scattered commissural fibres. In a sagittal section the human splenium, instead of forming a bilaminar structure, appears to the naked eye to be solid, and is generally represented in figures as a somewhat club-shaped posterior extremity of the corpus callosum. Zuckerkandl even goes so far as to say that it differs from that of most mammals in this respect, and graphically represents the supposed differences in two extremely crude schemes (*Ueber das Riechcentrum*, schemata 13 and 14, pp. 64 and 65). The splenium of the human corpus callosum, however, is distinctly bilaminar, just like that of any other mammal, and presents a well-marked inferior recurved portion (fig. 5, *ps'''*) composed of 'pallial' mixed with a very few 'hippocampal' fibres. This recurved portion is separated from the main mass of the corpus callosum by a small splenial recess, which is occupied in the mesial plane by an extension of the septum pellucidum. The 'septum' in this little recess contains a mass of fibres of the *fornix superior* (fig. 6), and it is this mass of fibres filling up the gap between corpus callosum and recurved splenium (fig. 6, *ps'''*) that gives the solid appearance (to the naked eye) of the human splenium. A magnified sagittal section, such as (fig. 6), immediately reveals the bilaminar nature of the splenium, and its resemblance to the arrangement in other mammals.

In this *Journal*, I announced last year ("The Morphology of the True Limbic Lobe, &c.," vol. xxx.) the discovery of a *fornix longus* in the human brain. Koelliker has since then (*Gewebelehre*) described it, and figured that portion which breaks

through the 'body' of the corpus callosum. In fig. 6 that portion of the *fornix superior* which breaks through the human splenium is represented.

Koelliker, like Ganser, Meynert, and Huguenin before him, attributes to the *fornix longus* an origin from the *gyrus fornicatus*.



FIG. 5.—Scheme of Human Commissures.

In the account given in this paper I have not referred to any such origin, because I have failed to clearly establish it. Although in certain sagittal sections appearances lend themselves very deceptively to such a conclusion, I have not found any supra-callosal connections of the *fornix superior* apart from those

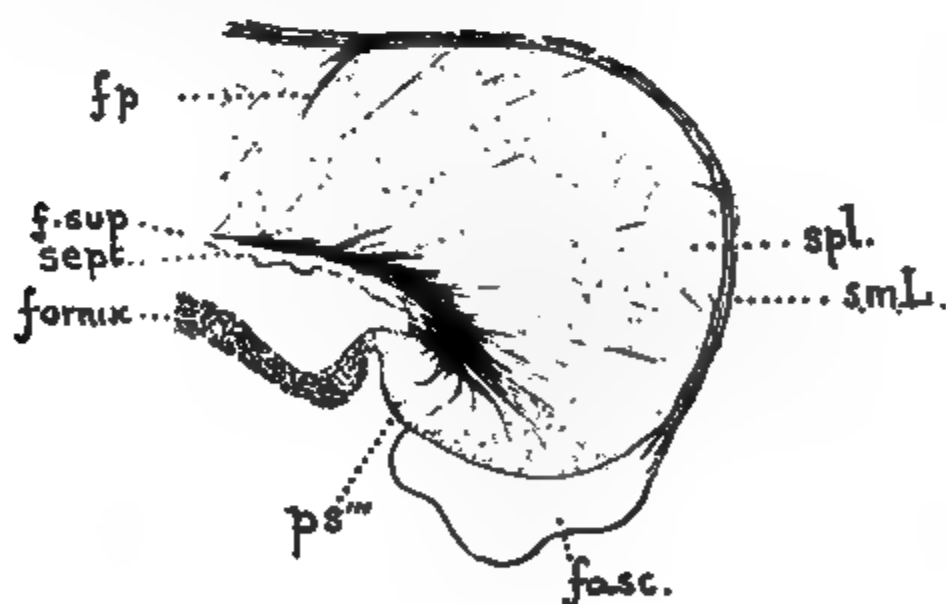


FIG. 6.—Human Splenium.

which it establishes with the *striae Lancisii* and other fibres of the 'dorsal limb' of the hippocampus (which do not belong to the *gyrus fornicatus*, but to the *fornix system*).

In regard to the lower mammals (marsupials), it can be

definitely stated that no such connection exists. And before it is admitted that fornix fibres extend their area of origin to a wider and histologically distinct cortical field, very definite and unequivocal evidence must be forthcoming.

Concerning the Functions of the Fornix.

The fornix consists of a series of association, commissural, and projection fibres of the hippocampus. The hippocampus is intimately associated with the smell apparatus by means of some of the precommissural fibres.

But whereas the fascia dentata varies almost directly with the degree of 'osmatism,' and almost completely disappears in anosmatic animals, the hippocampus proper not only does not vary in size directly with the degree of macrosmatism, but exists in a well-developed form in anosmatic animals. Notwithstanding this, the hippocampus is relatively large in macrosmatic animals. From this, one might infer that the fascia dentata is wholly, but the hippocampus only partly, given up to the olfactory function.

The fornix, being the association system of the hippocampus, must be partly olfactory in function; but as it exists in a well-developed form in anosmatic animals, it cannot be wholly olfactory.

No special series of fornix fibres are wholly olfactory, since representatives of them all—commissural and longitudinal (fornix longus, fornix superior, striæ Lancisii, columna fornicis, and precommissural fibres)—exist in anosmatic animals (porpoise).

Certain of the precommissural fibres afford a path by means of which olfactory impulses reach the hippocampus *via* the septum or *via* the striæ Lancisii.

There is nothing to indicate what other function the hippocampus may have to perform.

But fibres, which are *not* olfactory in function (in addition to olfactory fibres), associate the hippocampus with the region of the head of the corpus striatum (precommissural fibres and striæ Lancisii), with the mammillary region (columna fornicis), and with the hippocampus of the other hemisphere (psalterium).

Fibres, which may be olfactory in function, associate the

hippocampus with the ganglion Habenulæ by means of the fornix and stria medullaris thalami.

The so-called 'olfactory bundle of the hippocampus' of Zuckerkandl consists of the *precommissural fibres* of the fornix, and is mainly *non-olfactory*, since it exists in a well-developed form in anosmatic mammals.

Since the fornix is thus a heterogeneous system of fibres, one is not justified in concluding that a region of cortex is olfactory in function because it is connected with the fornix. But Koelliker (*Gewebelehre*, p. 789) argues that because the gyrus fornicatus is connected with the fornix longus (as he believes) therefore it is olfactory.

DESCRIPTION OF FIGURES.

Fig. 1. Sagittal section of cerebrum of ox $\times 2$. Semischematic. Positions of Fascia dentata and Fimbria indicated in outline. *Fi*, Fimbria; *F.D*, Fascia dentata; *f.h*, Fissura hippocampi; *b.G*, 'band of Giacomini'; *flx*, 'hippocampal flexure'; *fasc*, Fasciola cinerea; *spl*, splenium corporis callosi; *ps'''*, ventral part of splenium (a mixture of a few hippocampal-commissural with very numerous non-hippocampal-commissural fibres); *ps''*, scattered fibres of the psalterium; *ps'*, the main bulk of the psalterium ('*ps. ventrale*' of Honegger); *c.f*, columna fornicis; *c.v*, *commissura ventralis* (seu *anterior*); *p.f*, precommissural fibres (so-called 'olfactory bundle' of many writers); *sept*, septum pellucidum; *f.l*, '*fornix longus*' (employed to signify *all* the longitudinal uncrossed fornix fibres); *f.sup*, '*fornix superior*' (the most dorsal fibres of the *fornix longus*—those perforating the splenium and corpus callosum proper); *f.p*, *fibræ perforantes* (*fornix superior*); *s.m.L*, stria mesialis longitudinalis (Lancisii); *g*, genu corporis callosi; *a*, fibres of the *fornix superior* which extend around the genu from the stria Lancisii (*s.m.L*) without perforating any commissure.

Fig. 2. A scheme to act as a key to the arrangement of the fibres in fig. 1, and designed to emphasise the fact that all longitudinal fibres of the fornix system (except the few labelled *a*) break through some part of the great dorsal commissure to enter the septum.

Fig. 3. Camera-lucida drawing of a sagittal section of the forebrain of *Perameles nasuta*, stained by Weigert-Pal method, to show the arrangement of the Metatherian fornix, $\times 6$. *olf*, bulbus olfactorius; *c.A*, the 'dorsal limb' of the hippocampus lying immediately above the dorsal limb of the fornix commissure, which is stained black but is not labelled; *f.d*, the fascia dentata of the 'dorsal limb' of the

hippocampus; *n.f.d.*, the nucleus fasciæ dentatæ: immediately below the letters are to be seen a number of nerve fibres in the hilum fasciæ dentatæ (the 'Wurzel des Alveus' of Koelliker) which are proceeding downwards and slightly forwards to pass through the dorsal limb of the fornix commissure just in front of its 'splenium'; *alv*, alveus; *c.r.*, corona radiata; *sept*, homologue of the septum pellucidum of higher mammals; *x*, fibres proceeding directly from the alveus (*alv*) of the 'dorsal limb' of the hippocampus to form some of the precommissural fibres (which are shown in the precommissural area, *p.a.*); *c.v.*, *commissura ventralis* (seu *anterior*); *t.o.*, tuberculum olfactorium; *o*, optic tract; *c.f.*, columna fornicis; *c.m.*, corpus mammillare; *t.t.m.*, tractus thalamo-mammillaris (Vicq-d'-Azyr); *p*, pons Varolii; *g.h.*, ganglion Habenulæ, from which the stria medullaris (unlabelled in the figure) arches forwards and downwards between *c.f.* and *t.t.m.*; *f.r.*, fasciculus retroflexus (Meynert's bundle); *h.f.*, hippocampal fissure; *a.c.q.*,—*p.c.q.*,— corpora quadrigemina.

Fig. 4 is a scheme constructed to act as a key to fig. 3, and for comparison with fig. 2. It will be noticed that fig. 4 is a reverse of the commissural region of fig. 3, so that it may be directly compared with fig. 2. *ps^d*, dorsal limb of fornix commissure; *ps^v*, ventral limb of fornix commissure; *spl'*, splenium of fornix commissure; other references as in fig. 2.

Fig. 5. Scheme of the commissures of the human brain, natural size. References as in fig. 2.

Fig. 6. Sagittal section of the splenium and neighbouring structures of a human brain, $\times 3$. Kultschitzky stain. References as in fig. 1.

BIBLIOGRAPHY.

For a very complete and critical examination and review of the literature of the subject up to the year 1890, as well as for some admirable micro-photographs of gold-stained sections of small mammalian brains, the reader is referred to Honegger's exhaustive work, "Ueber den Fornix," &c., &c., in *Recueil Zoologique Suisse*, Tome v., 1890, more especially pp. 272 *et seq.*

The *fornix longus* will be found figured and described in the following works in addition to the above:—

STIEDA, "Studien über d. centrale Nervensystem," *Zeitsch. f. wissensch. Zoologie*, Bd. xix., 1869 (p. 87). Note especially Taf. iii. fig. 61 *c'*—the first representation of the *fornix longus*; also same Journal, vol. xx., 1870.

FOREL, "Beiträge zur Kenntniss d. Thalamus opticus" (p. 19), figs. 5–8, *Sitzb. d. k. Akad. der Wissensch.*, 3te Abt., Bd. lxvi., 1872, Wien.

GANSER, "Ueber das Gehirn des Maulwurfs," *Morph. Jahrbuch*, Bd. vii., 1882.

In EDINGER'S "Vorlesungen," Ed. 4, 1893, there is a good figure of the *fornix longus* in the rabbit.

KOELLIKER, "Handbuch der Gewebelehre des Menschen, Bd. ii., zweiter Hälfte, 1896. See especially pp. 774-790, also figs. 637 (p. 507), 638, 639, 643, 795 (p. 772), 796, 797, 798, 800, 803, 806, and 807.

BEEVOR, "On the course of the Fibres of the Cingulum and the posterior parts of the Corpus callosum and Fornix in the Marmoset Monkey," *Philosophical Transactions*, 1891.

This paper is illustrated by large series of micro-photographs of Weigert-stained sections in various planes. Unfortunately, as usually happens in this mode of reproduction, most of the detail has been lost.

THE TOPOGRAPHICAL ANATOMY OF THE SPLEEN,
PANCREAS, DUODENUM, KIDNEYS, &c. ILLUSTRATED
BY A CAST OF THESE VISCERA HARDENED *In Situ*. By A.
BIRMINGHAM, M.D., *Professor of Anatomy, Catholic Univer-*
*sity, Dublin.*¹

DURING the past year I have hardened the viscera *in situ* in three subjects. So thorough was the hardening in one of these that the firmer organs, such as the kidneys, were almost of the consistence of wood, while the pancreas and suprarenals were perfectly fixed, and retained their form even under pressure. As most of the viscera were fairly normal, I thought it well, for teaching and other purposes, to make a cast of this specimen. I accordingly had one prepared, which, owing to the successful hardening, gave a most faithful reproduction of the original, even to the 'texture' of the viscera in the case of the pancreas and spleen. A picture of the cast, reproduced by a photographic process, accompanies this paper; and the following pages will be devoted chiefly to a description of the organs as they appear in the cast, with some remarks on their topography, as illustrated by it and by the other specimens which I have prepared. I need hardly add, that no illustration can give a true idea of such a structure as a cast of the abdominal viscera, with its varying outlines, its projections and recesses. To make out all the points referred to here, the cast itself must be consulted.

I shall first give the method followed in preparing the specimen and making the cast; the description and remarks will follow.

METHOD.

The body, that of a middle-aged male, was placed on its back and properly supported.

I felt that the shape of the plastic viscera must be modified to a slight degree by the pressure of the overlying parts when the body rests in this position; still, I was of opinion that equally

¹ Read at the Oxford meeting of the Anatomical Society of Great Britain and Ireland, July 1896.

weighty objections might be made to every other position,—to the erect, on account of the loss of tone in the abdominal wall; and to the prone and lateral, for the same reasons as when the body lies supine. On a consideration of the pros and cons of the case, I came to the conclusion that the latter was as satisfactory as any other position. At the same time, I believe it would be well to check the results obtained with the body in one position by comparison with others obtained under different conditions.

The left common carotid was opened in the neck, and a tube tied in the proximal end—the distal end was ligatured. The internal jugular vein of the left side was also opened, and subsequently that of the right. The openings in the veins were controlled by clips; and the object of making them was, of course, to allow of the return of injected fluids. The fluids were injected entirely by pressure from a can placed about two feet above the level of the table on which the body lay. The blood-vessels were first washed out by a few quarts of normal saline solution. If this be not done, the chromic acid solution used for hardening coagulates the blood in the vessels and prevents a free circulation. After the washing out, a solution of chromic acid in water, varying in strength from $\frac{1}{2}$ to 1 per cent., was injected constantly (by pressure, as explained above), for three weeks, the clips on the jugular veins being occasionally relaxed to allow excess of fluid to escape. At the end of three weeks the injection was stopped. There was by this time a distinct increase in the prominence of the abdomen, and in the size of the extremities, &c., owing to the infiltration of the connective-tissue spaces generally, but this in no way interfered with the shape and relations of the viscera, which appeared to be little or not at all affected. The abdomen, and subsequently the thorax, having been opened, it was found that the viscera were perfectly hardened, and that such structures as the diaphragm were absolutely fixed.

The abdominal cavity having been fully laid open without any disturbance of the contents, a photograph was taken. The great omentum was then removed, all other parts being undisturbed, and another photograph secured. In this way, removing part by part, and photographing at each step, the

state of things shown in the illustration was arrived at. It would, of course, have been well if the stomach, liver, and colon could have been preserved, but were this done little more than these viscera would be seen; for this reason it was decided that a cast in which the viscera mentioned were removed, and only those lying on the posterior abdominal wall preserved, would be more useful. The great vessels were exposed by removing the

FIG. 1.

mesentery and the peritoneum of the lower portion of the posterior abdominal wall. However, the exact peritoneal relations of the right kidney and suprarenal, of the diaphragm, pancreas, spleen, and some other parts were carefully preserved.

The abdomen having been thus prepared, there was made from it a 'piece mould,' bearing the exact impression of the various parts of the specimen. From this was subsequently

obtained the 'original' cast.¹ This original I went over in every detail, smoothing off irregularities, &c. in the usual way, and from it was taken a gelatine mould, in which the final casts, such as that shown in the illustration (fig. 1) were made.

DESCRIPTION AND REMARKS.

Liver.—None of the liver has been retained in the cast, for reasons already explained; but in removing it the whole of the inferior cava was carefully preserved. The portion of the diaphragm in direct contact with the gland is clearly indicated, as are the termination of some of the hepatic veins, and the recess in which the Spigelian lobe lay. This latter recess is, owing to the preservation of the cava, very distinct as a marked depression, bounded by the prominent vena cava on the right, and on the left by a prominence of the diaphragm, produced by the œsophagus piercing it above, and by the aorta lying behind it lower down. The illustration shows this *recessus Spigelii* indistinctly; but in the cast it is very well marked, and is seen to be lined by the posterior layer of the upper end of the small peritoneal sac. In removing the liver, I first cut the small omentum and freed the left lobe from all its connections; on lifting it forwards and to the right, I came to the recess mentioned, which was completely filled by a process of liver having a free anterior surface; I separated this piece of liver easily from the rest of the organ by cutting along its right border, that is, along the inner border of the cava; and having removed the rest of the gland, I proceeded to examine this process in detail. I recognised it as the Spigelian lobe, but I found that it differed from the Spigelian lobe of our text-books and of His's models as I understand them.

The Spigelian lobe is described and represented as an oblong mass sculptured on the posterior surface of the liver at the side of the cava, and only slightly marked off from the rest of the organ except at its lower end, where it projects prominently downwards. That is to say, it is merely a part of the surface of the liver marked off by certain bounding lines, and *not* a prominent projecting mass, almost completely cut off from the rest of the gland by the near approach towards one another of the fissure of the ductus venosus running outwards to the right,

¹ This I have handed over to Messrs Cassiani, of Wellington Quay, Dublin, for publication.

and of the vena cava projecting forwards into the liver substance. The latter description, on the other hand, applies exactly to the Spigelian lobe in the specimen from which the cast was prepared, and also, I believe, to the average state of the lobe

FIG. 2.—Horizontal section at level of 11th dorsal vertebra.—A, aorta; D, diaphragm; D.V, fissure of ductus venosus; S.L, Spigelian lobe; V.C, vena cava. The lesser omentum lay in the fissure D.V as far as the letter V. (From a frozen section.)

when *in situ*. Fig. 2 is a tracing from a frozen horizontal section through the liver. Fig. 3 shows it on sagittal section from another frozen body. In both, the condition of the lobe present in my specimen is reproduced,—namely, it has a

FIG. 3.—Sketch of the liver in Braune's Pl. II. (mesial sagittal section of female body).—D.V, fissure of ductus venosus; S.L, Spigelian lobe.

posterior surface directed backwards and a little to the left, which is lined by peritoneum and fits into the 'recessus Spigelii' described above; and an anterior free surface (of

greater extent than the posterior, as a rule) looking forwards and to the left, covered by peritoneum, and forming the posterior boundary of a fissure which is produced by the folding over towards each other of the Spigelian and left lobes, and at the bottom of which is found the ductus venosus (D.V). The fissure, taken altogether, cuts outwards and a little forward to within about 2 centimetres of the front of the cava; and, as will be seen on reference to fig. 1, this lobe is separated from the rest of the liver with the exception of an isthmus about 2 centimetres in width, by the fissure in front and by the cava on the right. A rather sharp left border separates the anterior from the posterior surface. This condition of the lobe, differing very much, as it does, from my reading of His's model, is altered when the liver is removed from the body by the opening up of the fissure and the flattening out of the Spigelian lobe, the form with which we are so well acquainted being thus produced.

Otherwise, I have found the liver to conform very closely to Professor Symington's description of the organ in Quain's *Anatomy*. I have, however, been much struck by its great depth in the vertical direction on the right side, which was partly due in this case to the over-distension of the transverse colon, which was filled with gas and doubled up over the front of the empty stomach. As a result, the liver was pushed over, and packed into, the right side of the abdomen, with a consequent increase in its vertical depth,—the whole showing very clearly the plastic nature of such viscera as the liver, and the way in which they may be moulded by the pressure of adjacent organs. Though this moulding may take place to a considerable extent, still it never, I believe, robs the organ of its characteristic, and what I may call its fixed, shape. There are those who hold that the forms of the organs obtained by hardening *in situ* are not really fixed forms, but that the viscera are plastic, and take for the time being, as a result of the pressure of surrounding structures, shapes which are artificially fixed by the hardening agent, and thus fictitious forms arrived at. Any one who has hardened the viscera in a number of subjects, and observed the regularity with which the definite form of each organ appears, cannot accept this view. It is, I think, much more probable that every organ has a definite fixed form; that it is plastic to a certain degree; and that it can be moulded by the pressure of

adjacent organs within certain limits, producing modifications of its fundamental form.

Stomach.—In the cast, only the ending of the œsophagus and a small part of the stomach close to the pylorus are shown. The rest was removed before making the cast. However, several points in connection with the relations of the organ can be made out. In the specimen from which the cast was prepared, and, unfortunately, in the other subjects which I hardened, the stomach was nearly empty. I have, however, carefully studied the condition of the stomach in these specimens, and I have arrived at the following conclusion :—

The empty or nearly empty organ is of an attenuated and modified pear-shape, not flattened from before backwards, as often figured. The wider end of the pear is directed backwards, and somewhat to the left. At the right side of this end, a considerable distance from its summit,—in fact, almost as far from the summit as from the pylorus, and towards the upper (anterior) surface,—the œsophagus enters. The long axis of the organ is directed at first, and for the greater part of its extent, nearly horizontally forwards, with an inclination to the right. For a distance of about 8 or 9 cm. from the pylorus the stomach scarcely exceeds the duodenum in diameter, beyond this, it expands and passes on into the body of the organ; about the junction of this narrow pyloric portion with the rest, the axis of the pear changes its direction; it is first strongly bent towards the middle line (a little to the right of which the pylorus is placed) to reach the pylorus, and about 4 or 5 cm. nearer to the pylorus there is a second bend (not so strongly marked) downwards over the ‘omental tuberosity’ of the pancreas, as will be explained more fully when speaking of the ‘stomach bed.’ I believe this to be the usual condition of the empty or nearly empty stomach,—a condition brought about by its inherent shape and the tonic contraction of its walls. Moreover, I can scarcely conceive how the organ could ever assume a flattened form with its anterior and posterior walls in contact, particularly when the surroundings of the stomach are considered.

It should be added to the foregoing, that the lesser curvature was directed to the right and backwards, the great curvature

forwards and to the left, and that at its right end this curvature lay immediately along the top of the omental tuberosity of the pancreas. This latter point will be referred to again when speaking of the pancreas.

Although I was not fortunate enough to meet with a distended stomach in any of the bodies which I hardened, I have nevertheless considered, when studying my specimens, how the organ would be influenced by distension. This, however, I had better postpone until I have referred to some points bearing on the relations of the stomach.

Nothing has attracted my attention more, in connection with the stomach, in all the specimens which I have hardened, than the striking and well-marked shelf-like arrangement which supports, at least, the undistended stomach, and which I have referred to elsewhere as the 'stomach bed,'—appropriately, too, as will be seen on a reference to the cast. This stomach bed is formed in the following way. The portion of the pancreas to the left of the middle line has, as will be shown later, a very considerable antero-posterior thickness; as a result, its upper surface (the anterior of His) is of considerable extent, it looks strongly upwards, and forms a large and important part of the shelf. As the pancreas passes to the left towards the spleen, it crosses the upper part of the kidney, and is so moulded on to it that the top of the kidney forms an extension inwards and backwards of the upper surface of the pancreas, and extends the bed in this direction. (This is not so well shown in the cast, owing to the low level of the left kidney.) On the other hand, the extremity of the pancreas comes in contact with the spleen in such a way that the plane of its upper surface runs with little interruption upwards and backwards into the concave gastric surface of the spleen, which completes the bed behind and to the left, and, running upwards, forms a partial cap for the wide end of the pear (stomach). To a certain extent an anterior prolongation of the bed is formed by the transverse mesocolon, which, passing forwards from the anterior margin of the pancreas, is stretched over and supported by underlying coils of small intestine in such a manner that it forms a little platform in extension of the upper surface of the pancreas in an anterior direction. Thus, with the addition of blood-vessels and con-

nective tissue, which fill the intervals between the several parts, and the covering of peritoneum, the bed is completed.

There is, moreover, a roof to this space in which the stomach lies, quite as distinct as the bed, though more simple in its constitution, and better recognised. It is formed above chiefly by the diaphragm and the under surface of the left lobe of the liver; anteriorly, the abdominal wall closes in the space; while the cap for the wide end of the pear is formed, as mentioned already, by the spleen below, and above this by the diaphragm curving upwards and forwards from behind the spleen. In this way there is formed a perfect, and I believe an almost constant, 'chamber,' in which the undistended stomach is contained. A striking demonstration of this can be obtained by removing the stomach very carefully, in a hardened subject, without displacing the liver, diaphragm, or other organs. Into the chamber, at times, part of the transverse colon may find its way. Of all the walls of this chamber there is none more interesting, or more definite, I believe, than the stomach bed.

As to the condition of the distended stomach. If I am correct in my contention that the undistended organ is in shape that of an attenuated and modified pear, that it lies in a chamber such as I have described, with its great curvature directed forwards and to the left, its long axis for the most part nearly horizontal and lying in a direction approaching the antero-posterior, and its wide end looking almost directly backwards, it follows, I think, that there can be no great change of direction in the axis when the organ is gradually filled. That is, I can scarcely see how the long axis could assume an almost vertical direction in the greater part of its extent, as usually described, without such a disturbance of the surrounding viscera—flattening of the pancreas against the posterior abdominal wall, &c.—as I think unlikely to take place unless as a result of extreme distension, or a pathologically dilated stomach. On the other hand, I am inclined to the opinion that when the stomach is gradually and moderately distended, it enlarges chiefly in a forward direction, and by that extension to the right which is usually taught.¹ This,

¹ This is largely due to the enlargement of the pyloric portion which, as explained above, is little greater in size than the duodenum when the stomach is empty.

too, would correspond to the fulness of the 'pit of the stomach' which is noticeable after a large meal. Further, I believe that there is an expansion of the organ in an upward, and to a greater extent in a downward, direction, the former accompanied by an elevation of the diaphragm and left lobe of the liver, the latter by a descent of the stomach bed. In other words, the empty stomach, on being gradually filled, does not change its 'lie' to any marked extent, except in regard to the movement of its pyloric end to the right; its axis is comparatively slightly disturbed, but there is a general expansion in all directions, particularly forwards and to the right, as here the walls of the chamber in which the stomach lies are least resistant. If any great enlargement in the vertical direction take place, with increased distension there must be a considerable flexure in the back of the organ, corresponding to the position of the pancreas.

Spleen.—In the specimen from which the cast was made the spleen was somewhat enlarged. This may possibly account for the displacement downwards of the kidney on this side, and the corresponding displacement of the suprarenal. In every other regard the spleen corresponds exactly with the description of the organ given by Professor Cunningham in this *Journal*, vol. xxvii. Its relations are perhaps a little modified by its slight enlargement, but not sufficiently to vitiate in any way the agreement with the description mentioned. Its relation to the phreno-colic ligament is well shown.

It can also be clearly seen in the cast that the inner and posterior part of the base rests on a fold of peritoneum, continuous with the left end of the transverse mesocolon, which passes inwards to the kidney from the splenic flexure, in much the same fashion as the phreno-colic ligament passes outwards. This is a relation which I have not looked for in time in my other specimens, and I cannot say how constant it may be; but it seems likely to be present with the blunt form of the tail of the pancreas, mentioned later on. It is seen indistinctly in the illustration, filling the interval which is apparent between the kidney and the colon below the pancreas, and opposite the phreno-colic ligament. In the cast it is very distinct, as the bulging of the base of the spleen covered by the fold is clearly shown in this interval.

Duodenum.—The most striking thing about the duodenum in the cast is the fact that nearly half of its curve lies in a plane not far from the sagittal, the remainder being nearly in the coronal plane. As I have found this to be the case in all my specimens, I would direct special attention to it, particularly as the duodenum is generally described and figured as if it lay practically in the coronal plane. In His's model, too, particularly when viewed from the front, the same idea is preserved.

I should explain here, that after removing the stomach, and also the jejunum immediately beyond the duodeno-jejunal flexure, I carefully stopped the lower end of the duodenum, and poured in through the upper end enough liquid gelatine to give the tube solidity, and to increase its rotundity, as it would be very difficult to get a good impression of the empty tube, which might collapse under the pressure of the plaster. Besides, we generally think of, describe, and picture the duodenum in a more or less distended, not in an empty condition. In pouring in the gelatine, the greatest care was taken not to disturb in any way the relations of the organ to the surrounding structures—of which, indeed, owing to the thorough hardening, there was little danger.

The pylorus lies a little over 2 cm. to the right of the middle line. From this the first part of the duodenum runs transversely to the right for half its length, that is, until it has cleared the bile duct, with the hepatic artery and portal vein (which structures can be seen in the illustration running up from behind the duodenum). Beyond this it bends sharply backwards, at the side of the cava, and then turning down, passes into the second stage. The second stage descends along the right side of the cava,—not anterior to it, as usually taught,—lying, of course, in front of the inner margin of the kidney. It comes into very close contact with the ureter after that tube leaves the hilum of the kidney; and for fully two inches at the junction of the descending and transverse stages it lies on the psoas muscle. At the lower end of this second stage the gut bends gradually forwards and towards the middle line, forming the beginning of the transverse stage; about the middle of the transverse stage it again enters

the coronal plane, in which it runs to the duodeno-jejunal flexure. The latter part corresponds very closely to the received description. The special points in reference to the duodenum brought out by the cast, to which I would direct attention, are then as follows:—(1) This loop of gut does not lie in the coronal or any one plane, as usually represented; the first half of the first stage and all beyond the middle of the transverse (or third stage) lie practically in the coronal, while the rest of the duodenum is moulded round the right side of the cava and vertebral column, and is placed almost in the sagittal plane, the transition from one plane to the other being more abrupt above, more gradual below. (2) The cava does not lie behind the descending duodenum, but entirely to its inner or left side. This I have found not only in my specimens with the organs hardened *in situ*, but also in frozen sections. (3) The close relation of the descending duodenum posteriorly, to the ureter and the right psoas for a considerable distance. With a distended stomach and a pylorus thrust to the right, probably the first part of the first stage would lie further from the coronal plane than is the case in the cast.

Pancreas.—This organ is probably more interesting than any other in the cast, partly because the pancreas changes so rapidly after death that there is rarely an opportunity of examining one in its natural condition, and also because it differs very considerably from His's model, and from the ideas which are, I think, generally held regarding its shape. However, as I have found the pancreas practically the same in my other hardened specimens, I believe the condition shown in the cast to be normal. The head and neck agree very closely with Professor Symington's description of these parts, as found in the 10th edition of Quain's *Anatomy*, with this slight difference, that the first stage of the duodenum lies above the head—not above the neck—and the pylorus lies above the neck, close to its junction with the head. It is in the *body* chiefly that the pancreas of the cast differs from the usual descriptions: first, in the distinct way in which it projects forwards as a prominent ridge into the abdominal cavity; secondly, in its great size, for it appears to be the most bulky part of the gland; thirdly, in the great extent of its under surface; and lastly, in its distinct sweep backwards round the

top of the kidney as it passes to the left, as well as in several minor details.

His's model represents the body of the pancreas as being flattened against the posterior abdominal wall, with anterior and posterior surfaces of considerable extent, looking nearly directly forwards and backwards, and with a very narrow inferior surface. In all my specimens, on the other hand, the body of the pancreas, instead of being flattened from before backwards, projects very prominently into the abdominal cavity by its anterior border, so much so that its upper surface contributes very largely to the formation of the stomach bed, as already explained. This portion of the gland is very distinctly prismatic, particularly towards the tail end; but, contrary to the usual teaching, I find that the three surfaces are of nearly equal extent, the inferior being practically as large as the superior (anterior of His). The posterior surface, of course, looks backwards, and has the relations usually described. The superior surface, generally known as the anterior, looks upwards and forwards (sometimes more upwards than forwards), is of considerable extent, shelf-like in appearance, and constitutes an important part of the stomach bed. It is slightly concave, corresponding to the convexity of the stomach. The inferior surface looks downwards and forwards; it is, as explained, of about the same extent as the superior; it rests at its left end on the termination of the transverse colon, at its right on the duodeno-jejunal flexure, and between the two it rests upon, and is apparently supported by coils of jejunum. The superior is separated from the inferior surface by a sharp and prominent anterior border, which is gradually rounded off as the neck is approached. (In the cast it is well marked at the left end only.) The omental tuberosity at the right end of the body is distinct, but it does not project against the lesser omentum—at least, when the stomach is empty; on the contrary, it appeared in great part below the great curvature,—the stomach, as explained before, bending down over it.

The foregoing is the state of the body exhibited in the specimen from which the cast was taken, and it agrees in all essentials with my other specimens. I believe that it gives the true state of the pancreas when the stomach is empty; for, as

already mentioned, the stomach was practically empty in all the bodies hardened. I must admit, however, that it is conceivable that a fully distended stomach might press back the organ against the posterior abdominal wall, to some extent flattening out the superior surface, and making it more anterior in direction, and reducing the inferior surface to much narrower limits; but I think, at the same time, that this is highly improbable.

The tail of the pancreas, I have found, may take one of two chief forms. It may be long and attenuated, when it runs backwards along the basal surface (Cunningham) of the spleen, curving in this course round the outer aspect ('anterior surface') of the kidney, and covered, when viewed from the front, by the splenic flexure of the colon. On the other hand, it may be stout and blunt, when it abuts against the lower part of the gastric surface of the spleen. The latter of these two forms is represented in the cast.

Kidneys.—In the specimen from which the cast was taken, the kidney of the right side lies at a higher level than that of the left, contrary to the general rule. This may be due, in part at least, to the extra pressure of the slightly enlarged spleen, reinforced, perhaps, by a small amount of pleuritic effusion which was present on the left side of the chest, disturbing the balance of pressures which (according to Professor Cunningham's views lately expressed in this *Journal*) is one of the chief factors in keeping the kidney in position. On the left, also, the hilum of the kidney looks more strongly forward than on the right side, and than normal. This might, perhaps, be attributed to the depression of the kidney, which, by increasing the tension on the renal vessels, would naturally draw the hilum round to the front. An additional renal artery and its accompanying vein on this side call for no special remark.

The peritoneal relations of the right kidney are carefully preserved in the cast, although not shown in the illustration. About the upper $\frac{1}{8}$ or $\frac{1}{9}$ of the anterior surface is uncovered by peritoneum, and was in direct contact with the liver; the lower $\frac{1}{4}$ or thereabouts is also uncovered, and was connected to the back of the colon. The intervening part is covered by peritoneum, and was overlapped by the liver. In other respects the kidneys agree with Professor Cunningham's and the text-book de-

scriptions, and call for no special notice. Attention should, however, be called to the small amount of left kidney which appears above the pancreas in the cast : this, of course, is not the normal state, and is due entirely to the low level occupied by this kidney.

Suprarenal Bodies.—In the cast the right corresponds to the description of Rolleston, with the following slight differences :— (1) The surfaces look more strongly in and out than in his description. (2) The capsule lies nearly entirely posterior to the cava, and can scarcely be seen when the cast is viewed full from the front. Hence it does not appear in the illustration. And (3) the peritoneum covers only a comparatively small portion (about $\frac{1}{3}$) of the anterior surface near the kidney. The vein is indistinctly shown in the cast, high up ; it is very short, and enters the back of an hepatic vein (seen near the top of the suprarenal) which joins the right side of the cava. The left suprarenal is hardly discernible in the illustration, just below and internal to the upper and inner end of the spleen. It appears at first sight to differ very much from Rolleston's account, but this is probably largely due to the depression of the kidney on this side, as a result of which, owing to the removal of the support which the kidney should give to its upper end, the long axis of the capsule is placed nearly horizontally. A part only of the gland (in the cast) appears above the pancreas. This part is crescentic in shape ; it lies almost in the sagittal plane, with its ends forwards and backwards ; and the whole structure is moulded to the side of the left crus of the diaphragm, the side in contact with the crus being slightly concave, the other correspondingly convex.

I believe that the surfaces of the suprarenal capsules look much more in and out than backwards and forwards, as usually described. In fact, they lie very close to the sagittal plane.

Large Intestine.—Only the splenic flexure, the descending colon, a small part of the sigmoid flexure, and the rectum have been preserved ; the other parts were removed, in order to show the structures which lay behind them. Attention has been already called to the connections of the splenic flexure when speaking of the spleen. It need only be added that the flexure does not ascend as far as usual into the hypochondrium, owing to the enlargement of the spleen. Nothing in the descending colon calls for remark ; it agrees exactly with the

description in the latest edition of Quain's *Anatomy*. The cast shows clearly the line of attachment of the sigmoid mesocolon. The upper part of the rectum is fairly distinct, but the remaining contents of the pelvis are only slightly indicated.

Esophagus, Ureters, &c.—The lower end of the œsophagus has been preserved; its opening in the diaphragm is well shown, as are the left and part of the right crura of the diaphragm.

Both ureters are shown clearly as far as the brim of the pelvis.

Below the level of the kidneys and the duodenum, the peritoneum has been removed from the posterior abdominal wall without preserving the lines of reflexion, except at the sigmoid mesocolon and in the pelvis, where the peritoneum remains undisturbed. Above, its relations to the kidney, suprarenal, and diaphragm on the right side are carefully shown. The posterior layer of the upper part of the small sac, opposite the Spigelian lobe, is very distinct, and the right phrenic vessels will be observed passing upwards and outwards beneath it on the diaphragm. As already explained, the phreno-colic ligament passing out from the splenic flexure, and a fold (connected with the last bit of the transverse mesocolon) passing inwards from it, are preserved; the latter forming, in this case at least, a sustentaculum lienis internum. The attachment of the transverse mesocolon is indicated by a coloured line. The two layers are separated by about $1\frac{1}{2}$ inches on the descending duodenum, they gradually approach as they pass to the left on the head of the pancreas, and they finally meet at the neck; beyond this the line pursues a course which corresponds fairly closely to the anterior margin of the pancreas until the left end of the body is reached, when it passes on to the under surface. Consequently, in the specimen from which the cast was taken, the back of the transverse colon was connected to the front of the descending duodenum at about its middle, and to the adjacent part of the head of the pancreas by connective tissue without the interposition of peritoneum, corresponding in this very closely to the condition shown in His's model.

Vessels, &c.—The true proportion between the size of the arteries and the veins is shown,—a matter of some interest, as this is the reverse of what is seen in ordinary dissecting-

room subjects, in which the arteries are injected, and the veins are empty and insignificant. The aorta calls for no remark. The cava has been preserved in its whole length by removing the liver without disturbing the vessel; thus what is perhaps an unusual view has been secured. Several hepatic veins are shown joining it, and there is still noticeable a part of a very strong flexure to the left which engaged the cava just as it approached the auricle: part of this flexure has been removed. The hepatic artery, hepatic duct, and portal vein are well shown in their characteristic position just above the first part of the duodenum. The hepatic artery can be followed to the coeliac axis, from which can be seen arising the stump of the gastric, and also the splenic. The extremely tortuous course of the latter vessels along the upper border of the pancreas is well seen, and a part of its companion vein can be made out in the cast (not in the illustration) lying inferior and posterior to the artery, on looking down behind the upper margin of the pancreas.

The superior mesenteric vein has been preserved down as far as the middle of the transverse duodenum; the corresponding artery is cut short to show the head of the pancreas winding to the left beneath the vessels. This recurved piece of the head runs as far as the left margin of the superior mesenteric artery. The gastro-duodenal artery is seen coming down behind the duodenum, quite close to (indeed, practically behind) the pylorus, and dividing into the right gastro-epiploic, which is cut short and pinned down to the pancreas (to prevent its being injured in making the mould), and the superior pancreatico-duodenalis, which runs downwards in a groove on the front of the head, a considerable distance from the duodenum, as described and pictured by Symington in Quain's *Anatomy*. The corresponding vein is seen running downwards and to the left, to join the superior mesenteric. The so-called inferior pancreatico-duodenal artery is not shown, for it lies on the *back* of the head, running downwards and to the right, behind the recurved part of the head. The names 'anterior' and 'posterior' pancreatico-duodenal would be less misleading than those at present used. The remaining vessels call for no special remark.

A small ridge is seen running out from the side of the right

psoas muscle; it is not indicated in the illustration, but in the cast it is very distinct, and is due to a raising up of the iliac fascia by a small branch of the ilio-lumbar artery, often seen in this situation. It is not to be mistaken for the crest of the ilium and the ilio-lumbar ligament, which lie at a higher level, about $1\frac{1}{2}$ inches above this ridge.

CONCLUSIONS.

The chief points which I have called attention to in the foregoing may be briefly summarised.

1. The lobus Spigelii of the liver has an anterior free surface as well as a posterior, and it lies in a special 'recessus Spigelii' on the posterior abdominal wall. The opinion is expressed that such viscera as the liver have definite fixed shapes, which may be modified but not destroyed by the ordinary pressure of adjacent organs.

2. The empty stomach is in shape that of an attenuated and modified pear, with its wide end directed backwards and to the left; the greater part of the long axis runs forwards and a little inwards in the horizontal plane, and turns to the right and downwards a few inches from the pylorus. Its great curvature looks forward and to the left, its lesser to the right and backwards. Special attention is called to the 'stomach bed,' which forms the floor of a chamber in which the stomach lies.

3. The spleen corresponds to Professor Cunningham's description. In the cast a *sustentaculum lienis internum* is present, formed in connection with the left end of the transverse mesocolon.

4. The duodenum does not lie in the coronal plane, as usually represented; the first half of the first stage and all beyond the middle of the transverse stage lie approximately in the coronal plane, the intermediate part is moulded backwards by the side of the cava, and lies almost in the sagittal plane. The cava does not lie behind the descending duodenum, but to its left. The duodenum is also closely connected behind to the right ureter and psoas.

5. The pancreas agrees as to its head and neck with Symington's description. The body of the pancreas projects forward

as a distinct ridge into the abdominal cavity, and is not flattened against the posterior wall. It is prismatic, but the three sides of the prism are nearly equal, the inferior surface being as extensive as the superior (or anterior). Two forms of tail are described,—one which is long and slender, and curves back beneath the basal surface of the spleen; the other short and stout, which abuts against the lower part of the gastric surface of the spleen. The omental tuberosity, with an empty stomach, does not come in contact with the lesser omentum, but lies in great part below the great curvature of the stomach.

6. The suprarenal bodies lie not very far from the sagittal plane; and the right is nearly entirely posterior to the vena cava.

7. The position of the inferior pancreatico-duodenal artery on the back of the recurved part of the head of the pancreas is described, and the names 'anterior' and 'posterior' are suggested instead of superior and inferior pancreatico-duodenal, as probably being more correct.

Several minor points are touched on, which need not be mentioned here.

THE USE OF COLOUR SCREENS FOR MICROPHOTOGRAPHY. By GEORGE BELL TODD, M.B. & C.M., *Professor of Zoology, Anderson's College Medical School, Glasgow.* (PLATE VII.)

DURING the past six months I have had the opportunity of studying the influence of colours obtained by the use of thin gelatine films used as screens on colourless living organisms, such as Protozoa, Rotifers, and ova of Echinoderms,—the results in many cases being quite marked, as details seen by ordinary reflected light became more prominent when a suitable colour, such as orange, red, carmine, or blue, was introduced; the idea being to give a temporary tint or colour to the whole microscopic field, the colour-rays passing through the colourless or nearly colourless organisms so as to tint them with the corresponding colour. The results obtained were embodied in a paper on "Colour Tinting and its Application to Microscopic Work," read before the Glasgow meeting of the Museums Association in July last.

Since then I have turned my attention to the effect of a colour screen for micro-photographic purposes, using thin films of coloured gelatine in place of glass colour screens, such as Garbutt's. I find that for objects that present great contrast in their structural elements, and which are difficult to photograph satisfactorily by the ordinary method, may be greatly improved by the use of a suitably coloured screen.

Through the kindness of Dr Thomas Reid, of the Glasgow Eye Infirmary (who is a most expert micro-photographer), I have been enabled to obtain micro-photographs of a transverse section of the rhizome of the fern (*Pteris aquilina*, the common bracken) in the following manner:—

1. By photographing the object in the ordinary way without any screen (see fig. 1), where it will be noticed that there is a want of detail in the more transparent and colourless parts of the section, such as the phlœm, xylem, vessels, etc., of the fibro-vascular bundles; also in the prosenchyma (parenchyma) sur-

rounding the bundles, and in which they appear embedded, except in areas where the walls of the cells are thickened, lignified, and brownish in colour (sclerenchyma); and lastly, in the cortical parts, epidermis and hypodermis.

The exposure is 20 sec. in incandescent gas-light, the development full. This example serves as a means of comparing the same object photographed by an *orange* and *red* screen respectively.

I may note that the colour screen used here was very simple in its application. It consisted in laying a thin film of coloured gelatine over the aperture on the stage, fixing the slide with the object immediately above it in the usual way, then carefully focussing and photographing.

2. The result (fig. 2) in the case of the *orange* screen shows a commencing improvement in the details, which are nearly wanting in the first case. The woody and lignified parts are seen to stand out more distinct, while the vascular structures in the bundles are now coming into view somewhat more clearly.

The exposure here is 40 sec. in the same light, or double that required in the first instance.

3. In the case of the *red* screen (fig. 3), there is to be seen general all-round improvement in the various details of structure, but especially in the elements of the vascular bundles, which are amongst the most transparent parts in the section; even the bundle-sheaths stand out more distinct. In fact, all the details are, as it were, levelled up to the surface.

The time of exposure in this instance, with the same light, is 40 sec., but may be considered rather under, so that with a red screen an exposure from $2\frac{1}{2}$ to 3 times that in the first instance could be given if necessary, with proportionate increase in detail.

I take this opportunity of pointing out the advantages of a screen, as there are many who may have failed to obtain favourable results in instances where great contrast exists between the characters and appearances of tissues or elements contiguous to one another. This method is most useful where it is not thought necessary to previously stain the specimen. I may mention that the plates used were isochromatic, and that the illustrations are copied from the actual photographs, which, with their respective negatives, require to be seen in order to be able to appreciate the real value of this method satisfactorily.

THE PLATYMERIC, PILASTRIC, AND POPLITEAL
INDICES OF THE RACE COLLECTION OF FEMORA
IN THE ANATOMICAL MUSEUM OF THE UNI-
VERSITY OF EDINBURGH. By DAVID HEPBURN, M.D.,
F.R.S. Ed., *Lecturer on Regional Anatomy, University of
Edinburgh.*

I. INTRODUCTION.

THE great majority of the femora which form the subject-matter of the present communication have already had some of their characters—more especially their dimensions and tibio-femoral indices—described by Sir William Turner in his “Challenger” Report on the Human Skeleton.¹ In view, however, of the value and importance of this collection, to which many noteworthy additions have recently been made, Sir William Turner, a few months ago, entrusted to me the interesting duty of re-examining the entire collection, for the purpose of determining the *indices* which form the title of this paper; and for this opportunity I cannot sufficiently express my indebtedness to him.

As a result of working through this collection of femora, I have already prepared a paper on “The Trinil Femur (*Pithecanthropus erectus*) compared with the Femora of various Savage and Civilised Races,” which appears in the present number of this *Journal*.² In the former paper I merely referred to special features on particular bones, and in the present one I propose to deal with certain of the general and mechanical features of the femur, as well as with the very important questions suggested by the different *indices* to be derived from the detailed measurements of the shaft of the bone in its upper, middle, and lower thirds. With these objects in view, tables of measurements have been compiled. I have not considered it necessary to extend the inquiry so as to include the discussion of such questions as the angle formed by the neck and shaft, the amount of curvature of the shaft in the antero-posterior direction, or the

¹ Part xlvii., 1886.

² *Jour. Anat. and Phys.*, Oct. 1896, p. 1.

length of the femur in a straight line as compared with its 'total oblique length,' because such questions were either outside the scope of my investigations, or had already been discussed by Sir William Turner in his "Challenger" Report.

The study of *indices* forms an extremely valuable means of comparison between the femora of different races, besides presenting in a graphic form the results of those complex influences which act upon the bone in modifying its shape,—influences which form the sum-total of those diverse modes of life in relation to the attitude and gait of the individual which characterise different races of mankind, and imprint themselves upon the bones so indelibly as to enable one to determine with considerable precision the race to which a particular group of bones belongs, merely from a close study of their principal features.

It is true that *indices* are open to certain fallacies, and in the appropriate places these will be indicated, but nevertheless they constitute an important basis for comparison.

The characters of a long bone, such as the femur, may be divided into two groups:—first, those in which it resembles any other similar bone; and second, those which are peculiar to itself, and through which it resembles the bones of that particular race from which it has been derived. Among the common characters of all human femora there may be mentioned its mechanical adaptation to man's erect attitude, both for purposes of support and locomotion, in consequence of which certain definite proportions exist between the diameter of its head and the maximum bicondyloid diameter, as well as between each of these and the total oblique length of the bone, while the shaft itself is mechanically constructed to bear and resist (up to the point of fracture) strain in definite directions. The special features of any long bone are, for example, its developmental length in relation to the total height of the individual, and such surface markings as depend upon personal muscularity; the latter, in their turn, throw light upon questions of gait, activity, and general modes of life, probably even on the occupation of the individual, and the nature of the surface contours of the countries inhabited by particular races, living or extinct.

Among special features to be hereafter noted, mention may

now be made of the extent of the articular surface of the femoral head; the form of the depression for the ligamentum teres; the infra-trochanteric ridge; the impression or ridge for the gluteus maximus; the external and internal longitudinal pilastric fossæ; the popliteal surface and the backward extension of the articular surface of the internal condyle.

There seems no reason, also, why the femur, as well as various other bones and certain of the soft parts of the body, should not—in respect of their variations from the accepted normal human types—provide a certain amount of vestigial information bearing upon their historical evolution and development. Upon all such matters light is thrown by the study of *averages* and *indices*, which, moreover, teach us much with regard to the limits of individual and racial variability.

II. MATERIAL EXAMINED.

The total number of human femora measured and examined was 142, made up as follows:—Maori, 15; Australian, 14; Andaman, 12; Negro, 9; Kaffir, 2; Creole, 2; Hindoo, 6; Bengalee, 2; Sikh, 2; Malay, 2; Chinese, 2; Laplander, 4; Eskimo, 4; from a mound at Melita, Manitoba, 2; Sandwich Islands, 5; Bushman, 2; from Sharoonah, East Bank of Nile, 1; Guanche (Grand Canary Islands), 3; from near an old Roman wall at Leicester, England, 9; femora obtained from Practical Anatomy Room, University of Edinburgh, 44. So far as the sex of these bones could be determined, 99 were male, 25 female, and 18, from various causes, were marked 'uncertain.' In addition to the above, I examined the following femora of the Anthropoid Apes:—Gorilla, 2; Chimpanzee, 4; Orang-utan, 2; Gibbon (*Hylobates syndactylus*), 2.

It is evident that the foregoing list presents no lack of variety, although in certain of the groups it is weak in absolute numbers. In dealing with the *averages*, I have calculated out and tabulated all the results obtainable from the various *indices*; but in regard to other averages, I have not summarised the results obtained from less than four measurements, as one can scarcely draw any conclusions from a smaller number, and it is even doubtful whether much reliance can be placed upon averages which are

calculated from less than twelve observations. Nevertheless it seemed advisable to calculate average *indices* from the figures at my disposal.

III. EXPLANATION OF THE INDICES.

1. *PlatymERIC Index*.—Sir William Turner some years ago called attention¹ to a remarkable flattening of the sub-trochanteric region of the shaft of the femur in the Maori and in some femora of other races. By reason of this flattening, the shaft presented more or less well-marked anterior and posterior surfaces, separated from each other by internal and external borders of varying degrees of sharpness. To the external of these borders Sir William Turner applied the name of the 'infra-trochanteric ridge,' but it was reserved for Professor Manouvrier of Paris to introduce the term *platymery* (flat femur) as descriptive of the condition, and this term has now been generally accepted.

Platymery in the sub-trochanteric section of the shaft is due to an increase in its transverse diameter, coincidently with a diminution of its antero-posterior diameter. The relation which exists between these two diameters is termed the *Index of Platymery* or *PlatymERIC Index*, and it is calculated, as recommended by Manouvrier, on the basis that the transverse diameter equals 100; thus

$$\frac{\text{Antero-posterior diameter} \times 100}{\text{Transverse diameter}} = \text{PlatymERIC Index.}$$

2. *PilASTRIC Index*.—On the posterior aspect of the middle third of the shaft the human femur presents the well-known *linea aspera*. From a careful study of the development and morphological significance of this so-called *line*, the alternative, and in some ways more accurate, term of *pilastre*, employed by Broca, has largely come into use in anthropology. Presenting itself as a backward projection, having varying degrees of prominence, the pilastre naturally tends to increase the antero-posterior diameter of the middle third of the shaft. Associated with this increase there is either an actual or a relative diminution of the transverse diameter, the result being the production

¹ "Challenger" Reports, *op. cit.*; *Jour. Anat. and Phys.*, vol. xxi. p. 488, 1887.

of a flattened appearance in a plane at right angles to the plane in which flattening may be seen in the upper part of the shaft. It is not advisable to have recourse to the term 'platymery' a second time as descriptive of the conditions of the middle third; and in order to avoid confusion, it is better to use the term *Pilastric Index* to express the relation between the antero-posterior and transverse diameters of the shaft in the region of the *linea aspera* or pilastre. Assuming, again, that the transverse diameter equals 100, then

$$\frac{\text{Antero-posterior diameter} \times 100}{\text{Transverse diameter}} = \text{Pilastric Index.}$$

3. *Popliteal Index*.—Below the level of the *linea aspera* the shaft of the femur expands in order to carry the articular condyles, and on its posterior aspect the margins or lips of the *linea aspera* separate from each other, and are prolonged as ridges, of variable distinctness and prominence, to the external and internal condyles respectively. These ridges constitute the lateral borders of the popliteal surface of the femur, and they are variously named the external and internal supra-condyloid ridges, or inferior pilastric prolongations. For purposes of comparison, it is necessary to express the relation between the transverse and antero-posterior diameters of this section of the shaft; and a *popliteal index* is calculated, again, as proposed by Manouvrier, on the basis of the transverse diameter being equal to 100. Since, however, the popliteal surface is subject to much variation, both as regards its contour and its width, *two* antero-posterior diameters are measured. Both of these are taken from the most projecting point on the front of the shaft, at a distance of 4 cm. above the superior articular border of the external condyle; while posteriorly, the one rests upon the external supra-condyloid ridge at a corresponding level, and the other in the middle of the popliteal surface equidistant between the two supra-condyloid ridges: the former is symbolised as "mn" and the latter as "mp." From these data, at the 4 cm. level,

$$\frac{\text{Antero-posterior diameter (mp)} \times 100}{\text{Transverse diameter}} = \text{Popliteal Index.}$$

In calculating the above *indices*, it is clear that they are all produced on the assumption that the transverse diameter = 100;

consequently the *index* represents the relation of the antero-posterior diameter to this standard. Thus, when an *index* stands at 100, it means that the actual antero-posterior diameter is *equal* to the actual transverse diameter. Again, when the *index* is *under* 100, then the actual antero-posterior diameter is *less* than the actual transverse diameter; and similarly, when the index is *above* 100, then the actual antero-posterior diameter is *greater* than the actual transverse diameter. In other words, indices of 100 show that the bone presents no flattening in one direction more than in another, but tends more or less distinctly to possess a cylindrical appearance; whereas *indices* above or below 100 indicate that the shaft shows a degree of flattening or expansion commensurate with the *index*, either in an antero-posterior or in a transverse plane.

Some additional facts have been included in these observations, such as the diameter of the femoral head and the maximum bicondyloid diameter. From these data, tables have been compiled to show the average relation between these, as well as the average relation which each bears to the total oblique length of the femur. Finally, I have thought it worth while to record the position and number of the great nutrient foramina seen on the femoral shaft, since the point where the nutrient artery enters can scarcely be a mere accidental spot, especially as the direction of this vessel is supposed to determine the more rapid growth of the upper end of the femur as compared with the lower end.

IV. METHODS OF OBSERVATION.

The 'total oblique length' was obtained by means of Broca's Osteometric Board. One would not expect that a rigid bone should give different results in the hands of different observers, and yet there is frequently a difference of one or two millimetres under such circumstances. This ought not to be so, and it is no doubt due to the method of handling the movable perpendicular which is applied to the head end of the bone. To obviate these discrepancies, I would suggest that the moving perpendicular should travel in a metal groove, after the principle of the instruments used by shoemakers in obtaining the length of the foot.

Diameter of the Head of the Femur.—Like all other diameters,

this was taken by means of steel calipers having semicircular arms and blunt points. Where possible, the measurements were checked by means of another calipers carrying straight arms ending in sharp points. The greatest diameter of the head was nearly always found in the vertical transverse plane, although occasionally this diameter would lie in the antero-posterior direction; but in most of these instances one millimetre would express the difference between the two directions when any difference really existed.

In obtaining the data for the Platymetric Index, Professor Manouvrier suggests that the *smallest* antero-posterior diameter be taken first; and at the level where this is found, that the transverse diameter be then measured. The point at which the smallest antero-posterior diameter is situated varies slightly in its distance below the small trochanter in each¹ bone. Professor Halliday Scott, of Otago University, measures this diameter at the level where the spiral line crosses below the descending root of the small trochanter; but as this does not in every case correspond with the smallest antero-posterior measurement, I have followed the method suggested by Professor Manouvrier. It is necessary to keep the posterior point of the calipers to the inner side of the gluteal ridge, especially when this ridge is situated directly upon the posterior surface of the shaft.

In measuring the diameters of the middle or pilastric section of the shaft, the *greatest* antero-posterior diameter is taken first. This may or may not correspond to the middle of the shaft,—in very many instances it lies below the middle of the shaft; —but wherever it be, at that level, the transverse diameter is also taken in a plane parallel to the posterior surfaces of the condyles.

It has been more difficult to obtain a fixed level at which to measure the popliteal diameters because of the shape of this section of the shaft of the femur; and as there is no natural landmark, an artificial line has been selected, which, as already indicated (*vide ante*), is at a distance of 4 cm. above the anterior articular surface of the external condyle. In all my popliteal measurements I have adhered to this 4 cm. level, although, as Professor Manouvrier has suggested, it is quite admissible

¹ *Trans. New Zealand Inst.*, vol. xxvi., 1893.

to somewhat increase or diminish this distance according as the femur be longer or shorter than the average.

The *distance of the linea aspera from the external condyle* expresses the vertical length of the popliteal surface of the femur. I have measured it from the posterior aspect of the external condyle upwards to a point at which it could be definitely determined that the margins of the linea aspera were diverging from each other. Of necessity, this upper point is far from being precise, although the amount of error can never be so great as to invalidate the value of the measurement.

The *maximum bicondyloid diameter* is the greatest width between the non-articular surfaces of the two condyles. It cannot be rendered if there has been damage to either the inner or the outer surface in this region.

The popliteal diameters "mn" and "mp" have already been explained. They are placed together in the tables for contrast. When "mp" is equal to or greater than "mn," then the popliteal surface of the femur tends either to flatness or convexity, which signifies that the general cylindrical form of the shaft has been prolonged to a lower level than is usually seen in modern European femora; for in them the rule is that "mp" is less than "mn," or, in other words, the popliteal surface is more or less concave.

V. DISCUSSION OF DETAILS.

One noteworthy feature of the collection of femora which I have examined is, that with the exception of the British specimens, the great majority are in natural pairs, and consequently one is constantly impressed with the great amount of variation which the two femora from one individual almost always present,—a variation which is not confined to one part of the bones, but affects them in nearly all their particulars. I have not seen any pair of femora which are absolutely symmetrical, although the nearest approaches to perfect symmetry were found in the femora of a Gibbon and a young Chimpanzee, while coming next in order there were pairs of Australian, Andaman, Kaffir, Negro, and Lapp femora.

1. *Total oblique length*.—The absence of uniformity in the total oblique length was very marked in most of the 'pairs'—the

greatest observed difference being 21 mm. in the case of the femora found in a mound near Melita, Manitoba. A difference of 14 mm. was noted in a pair of Australian female femora collected by the "Challenger" Expedition in Victoria, while differences of 6 and 7 mm. were found among pairs of Andaman, Negro, Hindoo, and Chinese femora. The usual amount of difference varied from 1 to 5 mm.

The shortest individual bone was from a female Laplander, in whom the right femur measured 357 mm. and the left 361 mm. In a male Andaman the right femur was 361 mm., while the same figure was recorded in a specimen belonging to Sir William Turner's teaching collection.

The longest femora examined, again, belonged to the same collection. Of these one measured 546 mm., and another 507 mm. A specimen obtained from the dissecting-room¹ measured 505 mm. The femur approaching most nearly to the above was that of a male Hindoo, which measured 504 mm.

By reducing the measurements of length to a series of averages, and including male and female in the calculation, we find that the Negro femora stand first at 459·6 mm. Coming next are the British at 459 mm., and after them the Australian at 458·7 mm. Five female femora from the Sandwich Islands averaged 404 mm., while only the Laplanders, at 380·5 mm., and the Andaman, at 375·1 mm., were below 400 millimetres. All those groups of femora which I have not entered in the table of averages, because of there being so few in each group, averaged above 400 mm.

2. *Diameter of femoral head.*—In this measurement a want of uniformity has also to be noted so far as the 'pairs' are concerned, although it was not so general as in the case of the length, and it only varied from ·5 to 1 mm.

The smallest diameter of the head was 34 mm., and it occurred in a female Andaman. The femoral head in none of the Andamans reached 40 mm., while the smallest measurement seen in a male Andaman was 35 mm. This diameter was also found

¹ As the presence of foreign subjects is a matter of extreme rarity in the dissecting-room, there is no strong reason for doubting the British origin of the femora quoted, more especially as they exceed in length any of the possible sources of error.

below 40 mm. in 2 Australian, 2 Negro, 2 Hindoo, 2 Lapp, 2 Sandwich Islands, and 1 dissecting-room femur, and in all of these cases they were from females. Except among the Andamans, no male femur had a head diameter less than 40 mm.

Fifteen femora showed a head diameter of 50 mm. and upwards. Of these, 11 were from modern Europeans, mostly British¹; 1 from the ancient bones found at Leicester, 1 from Manitoba, and 2 Sikh.

The largest head diameter was 57 mm. in a British femur.

Dealing with the averages of the head measurements, we may exclude the Sikh femora, since only two of them were examined. Of the remainder, the bones found near the Roman wall at Leicester yielded an average diameter of 47·8 mm. Next to these, the modern British femora gave 47·6 mm., the Maori 44·7, the Negro 43·8, the Hindoo 43·5, the Eskimo 43·2, Australian 42·5, Laplander 40·3, Sandwich Islanders (all females) 39, Andamans 36·1, and four Chimpanzee femora 31·5. A reference to the tabulated averages will show that the oblique femoral length is rather more than *ten* times the diameter of its head in the Australian, Andaman, Negro, Hindoo, and Sandwich Islands femora; but slightly less than ten times, in the Maori, Laplander, Eskimo, and British femora. Of the Anthropoid femora, the same proportions were found to be 11 in the Gibbon, 8·8 in the Chimpanzee, 7·5 in the Gorilla, and 7·3 in the Orang-utan. So far as these figures can constitute a basis of comparison, they place the Gibbon at one end of the human series, and the Chimpanzee, Gorilla, and Orang-utan at the other.

Passing from the consideration of the diameter of the femoral head to an examination of its articular surface, there are two outstanding conditions which deserve notice. In the first of these, the margin of the articular surface is sharply defined from the adjoining neck, and in the second, the articular surface encroaches more or less distinctly upon the anterior and upper aspect of the neck. In the bones under consideration, a

¹ With reference to the possibility of the British Collection having accidentally included foreign femora, of which Negro specimens are the most probable, it is interesting to note that of the British Collection 25 per cent. had head diameters of 50 mm. and upwards, while the highest Negro diameter was only 47 mm.

sharply defined margin to the articular surface characterised those of the Andaman, Australian, Laplanders, Bushman, Sandwich Islanders, Creole, Egyptian, Manitoba, from Leicester, and the great majority of the Maori and British femora. On the other hand, an encroachment of the articular surface on the neck of the femur was noted in four or five British femora, and in those of the Hindoo, Bengalee, Sikh, Malay, Eskimo, Chinese, Negro, Kaffir, one of the Sandwich Islands group, and in three of the Maori group. Professor Charles¹ of Lucknow has shown that this extension in the case of the Punjabi is to be associated with the attitude of squatting; and while there is every reason for accepting this explanation, it is evident from the above subdivision that a squatting attitude—as, for example, in the Australian aboriginals—is not always associated with this peculiar extension of the articular surface.

The depression for the attachment of the ligamentum teres was present in all the human femora, in varying degrees of distinctness, shape, and size. Two varieties of shape were noted—elongated in the antero-posterior direction, and circular. In those cases where the depression was deep, numerous well marked foramina occupied the fossa, but when the depression was shallow, the foramina were either small or entirely wanting, thereby leaving the bottom of the depression smooth, although always somewhat irregular. The extreme of elongation was seen in the Maori femora, and throughout this entire series the depression was markedly elongated, the antero-posterior length being frequently three times as much as the vertical measurement. An elongated outline also characterised this depression in the Laplander, Malay, Sikh, Hindoo, Egyptian, Chinese, and male Negroes, with one exception, although the depth varied greatly; while, again, in the Australian, Andaman, Sandwich Island, Bengalee, Bushman, one Hindoo, one male Negro, and the Negresses, the general aspect of the depression was circular, with occasionally slight tendencies to elongation.

Among the British femora a great deal of variety was shown; and while, for the most part, the depression was circular in type, yet there were instances of well marked elongation. In one femur the depression was not only elongated, but there was a

¹ Professor Charles, *Journ. of Anat. and Phys.*, vol. xxviii.

wide non-articular area, extending from the lower border of the depression downwards to the neck of the bone.

3. *Sub-trochanteric Region and PlatymERIC Index*.—The indices of platymery which I have noted vary from 58·8 in a Maori (fig. 1) to 115 in a British femur (fig. 3), and nothing could be more striking than the general appearances of these two bones; for whereas in the former the width is nearly twice as great as the antero-posterior measurement, in the latter the width is distinctly less than the antero-posterior diameter. I have also found this index as low as 58·8 in a Sandwich Island femur, and at 60 in an undoubtedly British femur. Again, while the British femur above referred to at 115 was quite healthy, another one of the same group (P), which presented evidence of rachitis, gave a *platymERIC index* of 122.

Apart from these extreme forms of platymery, the table of averages (*q.v.*) shows that this condition is most pronounced among the Maori femora where my measurements gave the average of 63·6, with limits of variation from 58·8 to 68·9. These results are calculated only on 14 bones, and Professor Scott of Dunedin records the average of 50 Maori bones measured by him at 64·3, with 54·8 and 81·3 as their limits of variation.¹

The five female Sandwich Island femora measured by me returned an average platymERIC index of 65·4, and the seven femora found at Leicester 67·7, so that in both of these groups there is a very well marked widening of this section of the femoral shaft. Although individual femora from other races may also present this condition of flat femur,—*e.g.*, British femora at 60 (fig. 2), 65, 67·6; Hindoo femora at 63, 67; and a Lapp femur at 67·8,—yet platymery is not a condition which affects any existing race to the same extent as it is found in the Maoris.

Notwithstanding the wide range of variation shown by the 43 modern British femora, the average *index* from them is 81·8, which is considerably lower than the average of 86·6 recorded by Professor Scott² for 20 European femora.

The highest average *index* recorded in my table is 88·3 for 4 Eskimo femora, but here the small number of observations detracts from their value. For any number of femora greater than four, the average of 82·2 for 14 Australian femora takes

¹ *Transactions of New Zealand Institute*, 1893, vol. xxvi. ² Scott, *loc. cit.*

precedence. Although the number of Anthropoid femora examined was small, yet for comparison their average indices may be noted here, viz., Gibbon 87·4, Gorilla 82·2, Chimpanzee 74·7, Orang-utan 75; and clearly none of these present any evidence of pronounced platymery, so that they are evidently not affected by those conditions which cause this peculiar form of flattening in the sub-trochanteric region.

For additional contrasts, certain of Professor Manouvrier's results may be referred to in this connection. In his memoir on *La Platymèrie*, the highest *index* recorded is 128 in an ancient Parisian (St Marcel) femur, and the lowest 56·4 from a neolithic femur of Crécy-en-Brie. An ancient Canary Islander yielded 58·8, while 10 modern French femora varied from 75 to 117·3, their mean *index* being 88·2. For modern Parisian femora the mean indices lie between 80 and 100.

Sir William Turner¹ has also described extreme degrees of platymery in human femora, apparently of neolithic age, from the Oban caves. In a right femur the platymeric index was 58·8, and in the left 56·4. These figures exactly correspond with the lowest indices recorded by Manouvrier and referred to above, but neither of them is so low as the minimum recorded by Professor Scott in the Maoris, although 58·8 occurs twice among the Maori femora which have passed through my hands.

Platymery, therefore, appears to be a condition which results from causes that affected a wide variety of ancient races; and although marked degrees of flat femur make their appearance among modern peoples, yet it is among the Maoris that it is really found as a racial character. There seems no reason to doubt that the configuration of the bone results from muscular development in response to some special form of active exercise, as Professor Manouvrier has suggested, such as hunting and climbing over rough ground. An examination of the sub-trochanteric section of the shaft of a femur presenting well marked platymery reveals the presence of inner and outer borders, usually very distinct; the latter has been named by Sir William Turner the *infra-trochanteric ridge*, and, as a rule, it fades away more or less abruptly opposite the lower end of the rough

¹ Sir William Turner, "On Human and Animal Remains found in Caves at Oban, Argyllshire," *Proc. Soc. Antiq. Scotland*, 1895.

impression for the insertion of the gluteus maximus muscle. The anterior surface of this section of the femur may present a convex contour, or it may be hollowed out immediately below the anterior inter-trochanteric ridge, which in some cases may be partially reduced, and even rendered somewhat concave.

On the posterior surface of the shaft, the gluteal impression in such bones is usually not only a prominent feature, but becomes extremely important, from the frequency with which its upper end is enlarged to form a *third trochanter*. In an ordinary European femur the gluteal ridge occupies a median position upon the posterior aspect of the shaft, but in those which show platymery it is situated nearer to the outer than to the inner aspect of the bone. Sometimes it is separated from the infra-trochanteric ridge by a longitudinal groove or flat area; at other times no such groove is seen, and then the gluteal ridge appears to be placed upon the posterior aspect of the infra-trochanteric ridge. The extreme form of this relationship was seen in the Sandwich Island and Maori femora, for in them the gluteal ridge formed a prominent feature when the shaft was viewed from the external aspect. Indeed, in these femora the gluteal ridge was placed postero-externally, and in one instance the gluteal ridge was in reality situated upon the external aspect of the infra-trochanteric ridge. As already stated, Manouvrier associates platymery with active exercise over hilly country; and he accounts for the flattening of the bone through the increased development of the upper ends of the vastus internus and crureus muscles, upon which increased strain is thrown in the act of extending the knee-joint when the sole of the foot rests upon the ground as in climbing. There is no doubt that this explanation is correct; but extension of the knee-joint must be accompanied by extension of the hip-joint, in the production of which the chief factor is the powerful gluteus maximus. In all acts of climbing or ascending inclines, this muscle raises the trunk by extending the hip-joint; and in platymeric bones, the frequent presence of a *third trochanter*, as also the peculiar position of the gluteal ridge, indicate increased activity and power on the part of the gluteus maximus. The sub-trochanteric region of the shaft is thus placed between two sets of forces, and the result is the gradual increase in its width, and diminution in

its antero-posterior diameter. In order that these modifications may result, we have to suppose a very frequent flexed condition of the hip- and knee-joints, and therefore other osseous changes are sure to follow; and Manouvrier and Turner have pointed out the concurrent association of platyknemia with platymery. It is also worthy of note that a flexed condition of the hip-joint is the position in which the glutei medius et minimus lose their power of abductors, and become *internal rotators* of the femur; and it seems to me that in this coincidence there lies part of the explanation of the great amount of inward rotation that many femoral shafts exhibit, as well as of the manner in which the head and neck of these bones appear to project forwards to an unusual extent. There was no trace of a *third trochanter* in any of the Anthropoid femora which I have examined. In the Gorilla and Orang the gluteal ridge was placed upon the external lateral aspect of the bone, but in the Chimpanzee it was not so distinctly lateral in position; and, as has already been mentioned, the degree of platymery was not very pronounced in any of them.

4. *The Middle Section of the Femur and the Pilastric Index.*—It is in this portion of the femoral shaft that the cylindrical character is most developed. On the anterior aspect it is smooth and convex from side to side. Posteriorly there is a rough area of *linea aspera*, the lateral margins or lips of which stand out with varying degrees of prominence, and are continued both upwards and downwards into the adjoining portions of the shaft as ridges, which form characteristic features of the regions where they are placed. In certain femora the *linea aspera* is carried backwards as a crest or pilastre, whereby the antero-posterior diameter of the shaft is increased relatively to the transverse diameter, and in consequence the shaft appears flattened in the transverse direction. The *index* which expresses the amount of this form of flattening is called the *pilastric index*. In such bones the shaft presents a somewhat prismatic transverse section, and each postero-lateral surface tends to be somewhat concave. These lateral hollows may be described as external and internal longitudinal pilastric fossæ. The external fossa is the more distinctly developed of the two. It corresponds closely with the attachment or origin of the

vastus externus muscle. The internal longitudinal pilastric fossa, *e.g.*, Eskimo and Negro, is usually very shallow, and is frequently replaced by a flat surface, which may even become distinctly convex, as in Chinese and Kaffir. These features of this section of the shaft result from the attachments and varying degrees of development of the vasti and crureus muscles. According to Manouvrier,¹ the vastus externus is responsible, not only for the main characteristics, but also for the position in which we find the gluteal ridge, since, by the upward extension of the vastus externus, the fossa which it occupies is carried in front of the gluteal ridge, which is thereby thrown backwards upon the posterior aspect of the shaft. The same observer also accounts for the presence of a pilastre situated between the origins of the vastus externus and vastus internus muscles, exactly in the manner in which the *crests* are formed on the cranium of the gorilla, between its temporal and occipital muscles. Consequently there is a close relationship to be expected between the amount of flattening in the antero-posterior direction (*platymeric index*) and the amount of flattening in the transverse direction, as expressed by the *pilastric index*. Subject to individual variations, the general results which I have obtained harmonise with Manouvrier's conclusion. The highest individual *pilastric indices* which I have obtained were found on the femora of an Australian from Riverina, N.S.W., in whom the right bone gave an index of 132, and the left an index of 148 (fig. 4), bringing out very distinctly that absence of uniformity which characterises nearly all the features of a pair of thigh-bones. *High indices* were recorded as follows:—one Negro femur, 131·9; modern British femora, 130·7, 128, 126; Creole and Eskimo, 123; Bushman, 121·7. The range of variation in fifteen Maori femora was from 100 to 126.

The *lowest indices* I have measured were in the following femora:—one modern British, 85·7 (fig. 6); one from near a Roman wall at Leicester, 91·8; one Sikh, 91; one Negro, 96·4; two Chinese, 96; two Andaman, 100; three Maori, 100; in the Eskimo and Australian groups, the lowest recorded indices were 112·9.

¹ Manouvrier, "Étude sur les variations morphologiques du corps du fémur dans l'espèce humaine," *Bull. Soc. d'Anthrop. de Paris*, Oct. 1892.

Turning to the consideration of the averages obtained from an examination of four or more femora, these may be arranged as follows:—Australian (14 bones), 122·2; Eskimo (4 bones), 118·4; Negro (4 bones), 114·5; Andaman (12 bones), 113·4; Sandwich Islands (5 bones), 112·6; Maori (15 bones), 110; modern British (43 bones), 109·3; Hindoo (6 bones), 107·2; Laplander (4 bones), 105·8; 8 femora from near a Roman wall at Leicester, 98·3.

A reference to the accompanying table of average *indices* will show that, while the low platymeric indices of the Maori are associated with comparatively high pilastric indices, yet it is not the case that the *lowest* platymeric indices are found in conjunction with the *highest* pilastric indices. Professor Scott, from the examination of fifty Maori femora, obtained an average pilastric index of 115·8, with variations between 96·4 and 138; and even when we make allowance for the fact that his calculations of this index have reference to the *middle* of the femoral shaft, and not, as in my measurements, to the level of the greatest antero-posterior diameter, yet the Maori does not possess the highest pilastric index.

My averages show that the pilastric index of the Maori is exceeded by that of the Australian, Eskimo, Negro, and Andaman groups of femora, in none of which is the platymery a marked feature. On the other hand, in the British, Hindoo, and Lapp femora, whose platymeric index is higher than that of the Maori, the pilastric index is less than that of the Maori.

It is certainly a remarkable fact that the femora from near the Roman wall at Leicester should present such well marked platymery as is indicated by an average index of 67·7, and at the same time only show an average pilastric index of 98·3.

Facts like these force me to the conclusion that while the 'femur à pilastre' is certainly associated with the most pronounced conditions of platymery, yet high degrees of the two conditions may present themselves quite apart from each other, and consequently those conditions result from two distinct sets of causes, which may likewise operate together or separately. It is only, therefore, in a general way that I can corroborate Manouvrier's statement that a low pilastric index is associated with '*platymérie accentuée*'—(the femora from Leicester illus-

trate this point),—and that a high pilastric index is associated with '*platymèrie nulle*,' as shown by the Australian femora. On the other hand, the Maori femora, in which platymery is their most distinctive characteristic, gave, as already stated in my group of fifteen, an average pilastric index of 110, and in Professor Scott's fifty an average pilastric index of 115·8.

5. *The Popliteal Section of the Femoral Shaft and the Popliteal Index.*—As I have recently discussed this region of the femur in a separate paper,¹ it is not necessary to do more than shortly to summarise its measurements and averages in order to bring them into contrast with the platymeric and pilastric indices. At an earlier stage in this paper I have indicated the level at which the measurements necessary for calculating the *popliteal index* are taken, as well as the significance and value of the antero-posterior diameters "mn" and "mp," and the general features of the popliteal surface of the femur.

The lowest individual popliteal indices among the human femora were 65 in the case of a fragmentary femur found near the Roman wall at Leicester, and 66 in a British femur (fig. 9) obtained from the dissecting-room. It is quite evident that these figures indicate a very considerable amount of antero-posterior flattening. When, however, these are compared with the lowest index of the Gorilla, which was 50·9 (fig. 10), the difference in the shapes of the respective bones will be readily appreciated.

The highest popliteal indices were found in three Australian femora, viz., 96·9 (fig. 8), 93·5, and 91. Coming close after these, a Negro femur gave 90, and one British 89·7. The popliteal indices of the two Gibbon femora formed a remarkable contrast to those just stated, for at the 4 cm. line one femur gave an index of 100, and the other 102·5, that is to say, these two bones possessed popliteal indices higher than their pilastric indices—the only instances of such a condition throughout the entire series of my observations. If, however, we admit that a distance of 4 cm. above the external condyle is an excessive amount to allow for bones whose total length was only about 205 mm., and make measurements at a distance of 2 cm. above the external condyle, then the resulting indices of the two bones were 81·5 and 88,—

¹ "The Trinil Femur (*Pithecanthropus erectus*) contrasted with the Femora of various Savage and Civilised Races," *Jour. Anat. and Phys.*, Oct. 1896.

figures which are in no way remarkable as a contrast to the pilastric indices, although sufficient to give the Gibbon precedence among the Anthropoid Apes in respect of this index.

If we compare the popliteal indices from the point of view of averages, we find the 14 Australian femora gave 85·3; 6 Hindoo, 82·8; 9 Negro, 81·8; 43 British, 78·1; 2 Bengalee femora, 87·2; 2 Creole, 85; 2 Kaffir, 82·5; and 2 Bushman, 81.

It is necessary, in considering these indices, to keep constantly in mind that a small transverse diameter is just as effective in producing a high index as a large antero-posterior diameter, and therefore high popliteal indices require to be checked as regards the question of the convexity of the popliteal surface by a comparison of the diameter "mn" with that of "mp."

Another very important consideration in this connection is the absolute vertical length of the popliteal surface. In the tables this measurement is included under the head of "distance of linea aspera from external condyle," and I have reduced that set of figures to a series of averages. As a result I find that in the Australian, Negro, Andaman, Sandwich Island, Guanche, and modern British femora, the vertical length of the popliteal surface ranges from 100·3 mm. in the British to 111 mm. in the Australian. In the few Guanche femora available, the average was 115. On the other hand, in the Bushman, Hindoo, British (from near Roman wall), Maori, Lapp, and Eskimo, the same measurement ranged from 97·5 in the Bushman to 77·7 in the Eskimo.

The value of these averages is at once evident when we tabulate the groups in which occur the instances of the diameter "mp" greater than "mn." I have observed this condition in twenty-seven of the human femora which have been under consideration. These occurred as follows:—Andaman, 5; Guanche, 2; Australian, 3; Negro, 3; modern British, 8, although two of these may be regarded as due to pathological conditions; Hindoo, 2; Bushman, 2; Lapp, 1; Eskimo, 1. Now, it will be seen that twenty-one of these were associated with a popliteal surface over 100 mm. in average vertical length, and only six with a popliteal surface of less than an average of 100 mm.

Twenty-three of the above cases occurred in those groups where the average total oblique length of the femora varied from 3·4 to 4·4 times the average popliteal length, and only four

cases occurred among Hindoo, Lapp, and Eskimo groups where this ratio was from 4·7 to 4·8. In the Maori group the ratio was 4·9, and no instances of "mp" greater than "mn" were seen.

It appears, therefore, that one is more likely to find "mp" greater than "mn" when the popliteal surface is long rather than when it is short, whereas with a short popliteal space one would have expected that the pilastric conditions would have tended to increase the antero-posterior diameter "mp."

In the various tables an *index* is established between the transverse popliteal diameter at 4 cm. and the maximum bicondyloid diameter, on the basis of the latter being equal to 100.

The influence of this index upon both the *popliteal index* and the diameter "mp" seems to be erratic and uncertain, although, as an expression of the mechanical proportions between two important parts of the femur, it is of much interest. Thus we find this index demonstrating by its *averages* that in modern British femora the maximum bicondyloid diameter is exactly twice the transverse diameter of the shaft at 4 cm. above the external condyle. In the Eskimo, the maximum bicondyloid diameter is slightly less than twice the transverse popliteal diameter, but in all the others it is greater than twice, until the limit is reached in the Andaman and Negro, where the average of 43·7 indicates a very narrow shaft in the popliteal region in relation to the bicondyloid diameter.

Not only are high popliteal indices to be looked for in those cases where the transverse popliteal diameter is not greatly in excess of the transverse diameter of the shaft in the pilastric region, but under these conditions the diameter "mp" tends to be proportionately larger on purely mechanical grounds. Other conditions, causing a fulness which may amount to a convexity in the popliteal space, are the attachments of muscles and aponeuroses more extensively developed than usual. There seems no reason to doubt that the peculiar condition of the upper end of the popliteal surface of the Gibbon is due to its special muscular and aponeurotic attachments.¹

So far as the diameters "mn" and "mp" are concerned, a comparison between them shows that, in the great majority of

¹ See my paper on the "Trinil Femur," etc.

cases, "mn" is greater than "mp," although there is a sufficient frequency of the reverse condition to enable us to regard it as a human character. The extent of "mn" depends upon the prominence of the external supracondyloid ridge, to which the vastus externus muscle and the external intermuscular septum are attached. The internal supracondyloid ridge is always feebly developed, by reason of its relationship to the femoral artery. The diameter "mp" may be greater than "mn" for two reasons:—first, the external supracondyloid ridge may fall forwards upon the lateral aspect of the shaft instead of maintaining the posterior position from which it starts at the lower end of the *linea aspera*, so that at the level of the 4 cm. line "mn" is shorter than "mp"; second, either with or without the association of the first condition, the popliteal surface may present more or less of fulness, amounting in some instances to an actual convexity whereby "mp" becomes greater than "mn." Various explanations have been offered to account for this convexity. Thus it has been suggested that the vastus externus may be so attached as to prolong the pilastric conditions to a lower level than usual; but my own observations tend to show that it is with a long popliteal surface rather than with a short one that "mp" is found greater than "mn."

Again, I have elsewhere shown¹ that other muscular attachments may have an important influence in this direction, and in the whole series of Andaman femora which I have examined the upper two-thirds of the popliteal surface presented a distinct ridge prolonged downwards from the *linea aspera*. In some cases this ridge was situated midway between the lateral borders of the popliteal surface, in others it was nearer to the inner than to the outer border. Lastly, when the transverse popliteal diameter is small in comparison with the maximum bicondyloid and transverse pilastric diameters, it is quite conceivable that "mp" requires to be increased by way of providing a mechanical buttress to resist antero-posterior strain. In very young femora, and in certain pathological conditions, *e.g.*, rachitis, the popliteal surface also presents convex tendencies.

6. *Maximum Bicondyloid Diameter*.—This diameter is important, since it is through the condyles that the superincumbent

¹ Hepburn, "Trinil Femur," *loc. cit.*

weight is transmitted to the tibia. I have studied it from three points of view: first, its average diameter in the different races; second, its relation to the total oblique length of the shaft; third, its relation to the diameter of the femoral head.

First, as regards its average diameter, the highest average was 83.3 mm. in the modern British group, and the lowest was 66 mm. in the Andaman series. Second, the proportion of the average oblique length to the average bicondyloid diameter varied from 5.4 in the Laplander femora and those found near Roman wall, to 6.1 in the Australian series, indicating that in the former the width of the condylar region was greater, in proportion to the length of the femur, than in the latter. In the modern British series this proportion was 5.5. In the Chimpanzee femora, the same proportion stood at 4.6, and in the Gibbon at 6.3; in the two Orang-utan femora, 4.4, and in the single available Gorilla femur, 3.9. Again, therefore, in respect of this proportion, as formerly seen in connection with the proportion of the total oblique length to the diameter of the femoral head, the Gibbon was separated from the other Anthropoid Apes by the entire series of human femora which I have examined.

The relation between the average diameters of the femoral head and the average bicondyloid diameters resulted in a very remarkable uniformity, so much so that it would appear as if this relationship formed a mechanical proportion, due to the erect attitude. Thus, the average bicondyloid diameter was 1.7 times the average diameter of the femoral head in *all* the series examined, with the following exceptions:—Andaman, 1.8; Sandwich Islanders, 1.9; Chimpanzee and Gorilla, 1.9; Orang-utan, 1.6.

7. *Position and Number of Nutrient Foramina.*—In consideration of the importance of the direction taken by the nutrient artery after it enters the shaft, I thought it advisable to measure the distance at which the nutrient foramen was situated from the lower end of the femur, more especially as the plane of the nutrient foramen is a landmark in the case of the tibia for the calculation of platyknesia.

I cannot say that any very definite result has been obtained. In several femora no nutrient foramen could be found. A third

of the entire number presented two nutrient foramina, one being situated in each half of the shaft, and sometimes it was the upper and sometimes the lower which was the larger. Of the femora which only showed one nutrient foramen, in two-thirds of the cases this opening was situated above the level of the middle of the shaft, and in the remainder below this level. It does not appear, therefore, the nutrient foramen of the femur can form a reliable landmark.

8. *The Condylar Articular Surfaces*.—These surfaces may be considered from two points of view: first, the absolute extent of the articular surfaces; and second, those features which may be regarded as distinctly *human*, as opposed to the *simian* type of articular condyles.

In all the human series the articular surface of the external condyle reaches a higher anterior level than the internal condylar articular surface. Posteriorly, there is a considerable amount of variation in the degree of prominence attained by the two condyles; for not unfrequently, where they adjoin the popliteal space, one or both condyles may become flattened, instead of remaining convex in the transverse direction. Further, in such cases, the internal condylar articular surface, in particular, is not delimited by a sharply defined margin from the lower part of the popliteal surface. It is specially noteworthy that the articular surface of the internal condyle may also be found more or less distinctly prolonged to the lower part of the popliteal surface in close proximity to the hinder part of the intercondyloid notch; and, moreover, this extension is simultaneous with the extension of the articular surface of the head of the femur already referred to. I have not seen either of the extensions referred to in the femora of Anthropoid apes, in which, the head of the femur, especially, has its articular surface projecting to a marked extent beyond the neck in all directions.

As regards the comparison of the human articular condyles with the simian, the differences are remarkably distinct. This is particularly seen in that part of the articular surface common to the two condyles, and situated in front of the intercondyloid notch. In the simian type this area forms a wide, shallow groove, not only concave from side to side, but with its margins forming the limits of the concavity. In the human type the

same area is likewise concave, but in a deeper or much more abrupt manner; and on the external condyle, especially, the concavity does not extend to the extreme margin of the articular surface, but is limited by a flatter area.

Again, the upper border of this region presents a horseshoe-shaped outline in the apes, which may be slightly higher on the inner aspect, as in the Gorilla and Orang-utan, or higher on the outer aspect, as in the Chimpanzee. In human femora, the upper border of this articular surface is invariably higher in relation to the outer condyle, and almost always presents a depression immediately opposite to the deepest part of the concave surface. Again, among the apes, the concave articular surface situated in front of the intercondyloid notch is also marked off from the inferior condylar articular surfaces by interruptions or notches, which break the continuity of the internal and external borders of the general articular surface. These non-articular encroachments may also be seen at the anterior end of the intercondyloid notch, where the widening of the notch and the sharpness of its angles are due to this cause.

Among human femora, the intercondyloid notch is, as a rule, wider posteriorly than anteriorly, where it is narrowed by a rounding-off of its angles through extension of the articular surface. Moreover, as a rule, the inner and outer borders of the general articular surface present only the faintest sinuosities to indicate the lines of fusion between the inferior and anterior articular areas. While the depths of these sinuosities is subject to considerable variation, probably the external one is the more distinct of the two, and the internal one is usually seen at a point relatively more anterior than in the case of the apes, in which it is the deeper. In consequence of this filling up of the lines of demarcation between the anterior and inferior condylar articular surfaces, which is such a markedly human characteristic, these articular surfaces in man derive a breadth and a sharpness of outline which are not to be found among the femora of Anthropoid apes.

of the entire number presented two nutrient foramina, one being situated in each half of the shaft, and sometimes it was the upper and sometimes the lower which was the larger. Of the femora which only showed one nutrient foramen, in two-thirds of the cases this opening was situated above the level of the middle of the shaft, and in the remainder below this level. It does not appear, therefore, the nutrient foramen of the femur can form a reliable landmark.

8. *The Condylar Articular Surfaces*.—These surfaces may be considered from two points of view: first, the absolute extent of the articular surfaces; and second, those features which may be regarded as distinctly *human*, as opposed to the *simian* type of articular condyles.

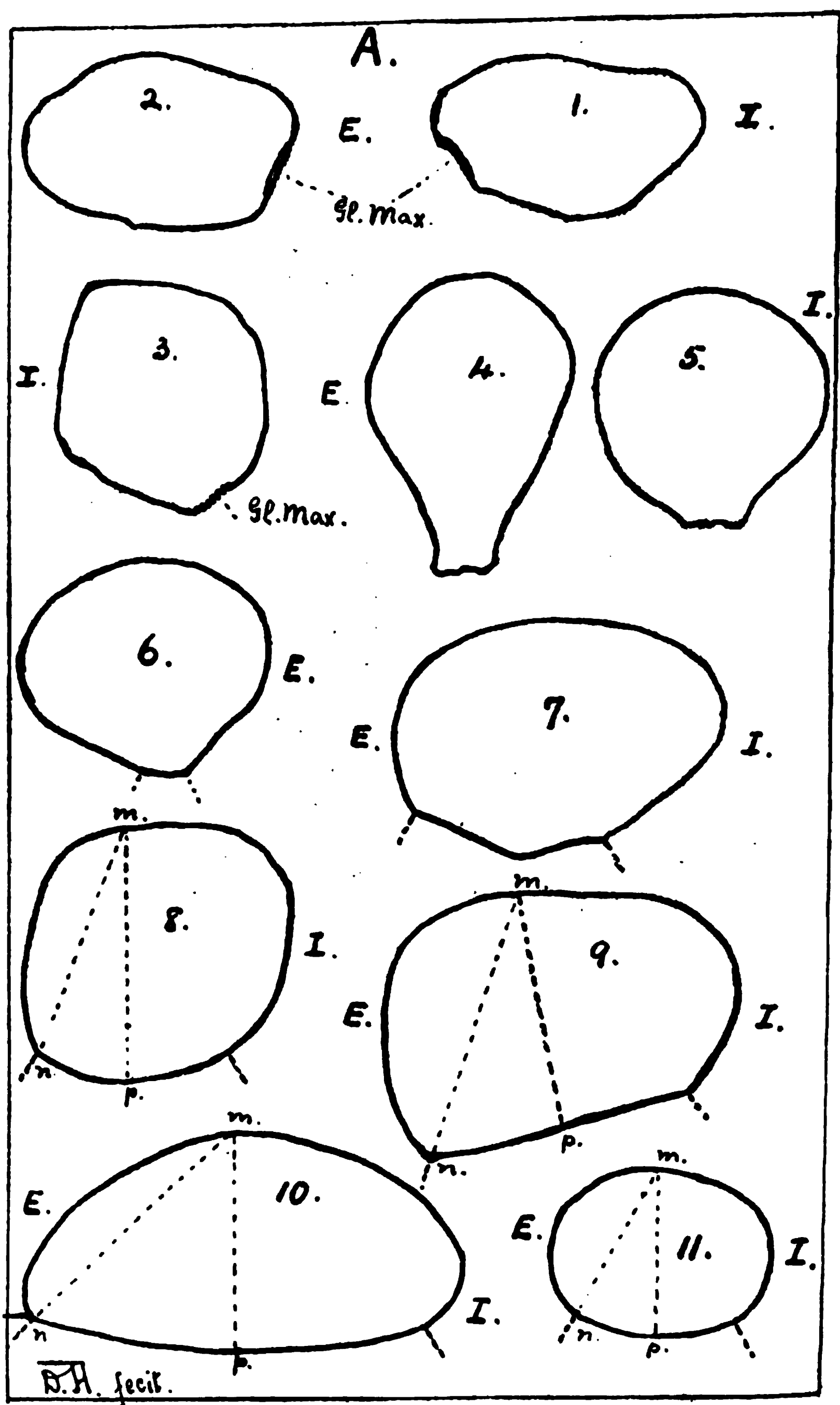
In all the human series the articular surface of the external condyle reaches a higher anterior level than the internal condylar articular surface. Posteriorly, there is a considerable amount of variation in the degree of prominence attained by the two condyles; for not unfrequently, where they adjoin the popliteal space, one or both condyles may become flattened, instead of remaining convex in the transverse direction. Further, in such cases, the internal condylar articular surface, in particular, is not delimited by a sharply defined margin from the lower part of the popliteal surface. It is specially noteworthy that the articular surface of the internal condyle may also be found more or less distinctly prolonged to the lower part of the popliteal surface in close proximity to the hinder part of the intercondyloid notch; and, moreover, this extension is simultaneous with the extension of the articular surface of the head of the femur already referred to. I have not seen either of the extensions referred to in the femora of Anthropoid apes, in which, the head of the femur, especially, has its articular surface projecting to a marked extent beyond the neck in all directions.

As regards the comparison of the human articular condyles with the simian, the differences are remarkably distinct. This is particularly seen in that part of the articular surface common to the two condyles, and situated in front of the intercondyloid notch. In the simian type this area forms a wide, shallow groove, not only concave from side to side, but with its margins forming the limits of the concavity. In the human type the

same area is likewise concave, but in a deeper or much more abrupt manner; and on the external condyle, especially, the concavity does not extend to the extreme margin of the articular surface, but is limited by a flatter area.

Again, the upper border of this region presents a horseshoe-shaped outline in the apes, which may be slightly higher on the inner aspect, as in the Gorilla and Orang-utan, or higher on the outer aspect, as in the Chimpanzee. In human femora, the upper border of this articular surface is invariably higher in relation to the outer condyle, and almost always presents a depression immediately opposite to the deepest part of the concave surface. Again, among the apes, the concave articular surface situated in front of the intercondyloid notch is also marked off from the inferior condylar articular surfaces by interruptions or notches, which break the continuity of the internal and external borders of the general articular surface. These non-articular encroachments may also be seen at the anterior end of the intercondyloid notch, where the widening of the notch and the sharpness of its angles are due to this cause.

Among human femora, the intercondyloid notch is, as a rule, wider posteriorly than anteriorly, where it is narrowed by a rounding-off of its angles through extension of the articular surface. Moreover, as a rule, the inner and outer borders of the general articular surface present only the faintest sinuosities to indicate the lines of fusion between the inferior and anterior articular areas. While the depths of these sinuosities is subject to considerable variation, probably the external one is the more distinct of the two, and the internal one is usually seen at a point relatively more anterior than in the case of the apes, in which it is the deeper. In consequence of this filling up of the lines of demarcation between the anterior and inferior condylar articular surfaces, which is such a markedly human characteristic, these articular surfaces in man derive a breadth and a sharpness of outline which are not to be found among the femora of Anthropoid apes.



EXPLANATION OF FIGURES.

All the figures give the actual size of the bones they represent at the level of the sections.

A, anterior surface in each case; E, external, and I, internal surfaces.

Figures 1, 2, and 3 represent the extremes of the conditions found in the sub-trochanteric region of the femoral shaft.

Figures 4, 5, 6, 7 represent extremes in the region of the *linea aspera*.

Figures 8, 9, 10, 11 are taken through the popliteal region at the 4 cm. line.

| | | |
|--|----------------------------|------|
| Fig. 1. Maori femur (left), Te Aroka. | <i>Platymetric Index</i> , | 58.8 |
| Fig. 2. British „ (left) (from Dissecting-room), „ | | 60.0 |
| Fig. 3. „ „ „ „ „ „ „ | | 115 |

Thus these two British femora present an entire change in the axis of flattening, *i.e.*, from the antero-posterior in fig. 2 to the transverse in fig. 3.

| | | |
|---|--------------------------|------|
| Fig. 4. Australian (Riverina) (left). | <i>Pilastric Index</i> , | 148 |
| Fig. 5. Shetland (left) | „ „ | 100 |
| Fig. 6. British (from Dissecting-room), „ | „ | 85.7 |
| Fig. 7. Gorilla (right), „ | „ | 73 |

Again, these sections show an entire change in the axis of flattening, from transverse in fig. 4 to antero-posterior in figs. 6 and 7, which therefore show no pilastre. The dotted lines below these figures indicate the limits of the area which corresponds to the *linea aspera*.

| | | |
|--|--------------------------|------|
| Fig. 8. Australian (Swan Hill). | <i>Popliteal Index</i> , | 96.9 |
| Fig. 9. British (from Dissecting room) | „ | 66 |
| Fig. 10. Gorilla, | „ | 50.9 |
| Fig. 11. Chimpanzee, | „ | 75 |

I desire to express my indebtedness to Dr Ramsay Traquair, of the Museum of Science and Art, Edinburgh, for permission to measure the femora of the Gibbon referred to in the text; to Mr Ewart, Student of Medicine, for the use of two Maori femora; and to Mr Arthur Preston, Student of Medicine, for his assistance in calculating the various *indices*.

FEMUR.

| Race. | Maori. | | | | | | | | | | | |
|---|---------------------|--------------|----------------------|--------|----------------------|--------|------------------|---------------------------|--------|-----------|-------------------------------------|--------|
| | Te Aroka, Auckland. | | E. Coast, N. Island. | | Locality not stated. | | Oti-popo, Otago. | Auckland, 'R.H. Makgill'. | | Wan-gani. | Nelson, P.D. Tasman Bay, S. Island. | |
| | R. | L. | R. | L. | R. | L. | L. | R. | L. | R. | R. | L. |
| Collection, | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. |
| Sex, | ♂ | ♂ | ♂ | ♂ | ♂ | ♂ | ♂ | ♂ | ♂ | ♂ | ♀ | ♀ |
| Age, | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. |
| Total Oblique Length, | 455 | 456 | 441 | 445 | 430 | 435 | 425 | 436 | 448 | 472 | 445 | 406 |
| Diameter of Femoral Head, | 48 | 47 | 44 | 44 | 43 | 44 | 41 | ... | ... | 46.5 | 45 | 42 |
| Diameters of Sub-trochanteric Region— | | | | | | | | | | | | |
| Antero-posterior, | 20 | 20 | 20 | 20 | 20 | 22 | 20 | 21 | 22 | 22 | 21 | 20 |
| Transverse, | 33 | 34 | 33 | 34 | 33 | 34 | 29 | ... | 33 | 34 | 30.5 | 31 |
| Platymetric Index, | 60.6 | 58.8 | 60.6 | 58.8 | 60.6 | 64.7 | 68.9 | ... | 66.6 | 64.7 | 68.8 | 64.5 |
| Diameters of Middle Region of Shaft— | | | | | | | | | | | | |
| Antero-posterior, | 28 | 29 | 27 | 28 | 27 | 27 | 26 | 29 | 29 | 28 | 27.5 | 24 |
| Transverse, | 24 | 24.5 | 26 | 26 | 27 | 26.5 | 28 | 24 | 23 | 26 | 22.5 | 24 |
| Platystic Index, | 116.6 | 118 | 103.8 | 107.6 | 100 | 101.8 | 113 | 120.8 | 126 | 107.6 | 122 | 100 |
| Popliteal Index, | 85.7 | 84.9 | 68 | 70 | 71 | 69.7 | 77.7 | 76 | 77 | 79.7 | 84 | 74 |
| (i) Popliteal Width at 4 cm., | 35 | 36.5 | 41 | 40 | 42 | 43 | 36 | 36 | 35 | 37 | 34.5 | 35 |
| (u) Max. Bicondylloid Width, | 87.5 | 86.5 | 77 | 77 | 77 | 78 | ... | ... | 78 | ... | 78.5 | 68 |
| u = 100; $\frac{u}{i \times 100}$ — | 40 | 42 | 53 | 51.9 | 54.5 | 55 | ... | ... | 44.8 | ... | 43.9 | 51 |
| Distance of Linea aspera from External Condyle, | 94 | 95 | 82 | 99 | 88 | 90 | 102 | 90 | 98 | 94 | 95 | 99 |
| "mn," | 31 | 31 | 32 | 32 | 32 | 32 | 29 | 31 | 31 | 30 | 29.5 | 28 |
| "mp," | 30 | 31 | 28 | 28 | 30 | 30 | 28 | 27.5 | 27 | 29.5 | 27 | 26 |
| Distance of Nutrient Foramen from Lower End of Femur, | 240 | None visible | 180 | 191 | 179 | 168 | 188 | 258 | 220 | 300 | 263 | 212 |

FEMUR.

| Race. | Negro. | | | | | | Negress. | | Kaffir. | | Creole. | |
|---|----------|----------|-----------|----------|--------------|----------|----------|----------|----------|----------|-----------|--------|
| | No. 1. | | Skeleton. | | Artic. Skel. | | | | | | Skeleton. | |
| | R. | L. | R. | L. | R. | L. | R. | L. | R. | L. | R. | L. |
| Collection, | U.A.M. ♂ | U.A.M. ♂ | U.A.M. ♂ | U.A.M. ♂ | U.A.M. ♂ | U.A.M. ♂ | U.A.M. ♀ | U.A.M. ♀ | U.A.M. ♂ | U.A.M. ♂ | ANAT. ♂ | MUS. ♂ |
| Sex, | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. |
| | 496 | 490 | 462 | 468 | 463 | 462 | 428 | 421 | 452 | 455 | 447 | 448 |
| | 45 | 44.3 | 47 | 47 | 45 | 46 | 39 | 39 | 42 | 43 | 45 | 44 |
| Region— | | | | | | | | | | | | |
| | 22 | 22.5 | 25 | 25 | 27 | 26 | 20 | 21 | 22.5 | 22.3 | 26 | 26 |
| | 29.5 | 28 | 34 | 34 | 31.5 | 31 | 27 | 28 | 28 | 29 | 30 | 30 |
| | 74.5 | 80 | 73.5 | 73.5 | 85.7 | 83.8 | 74 | 75 | 80 | 76.8 | 86.6 | 86.6 |
| Shaft— | | | | | | | | | | | | |
| Antero-posterior, | 30.5 | 31 | 28 | 30 | 33 | 33 | 32.3 | 25 | 23 | 23 | 32 | 32 |
| Transverse, | 24 | 23.5 | 29 | 28 | 28 | 27.5 | 22.3 | 23 | 23 | 24 | 26 | 27 |
| Pilastic Index, | 127 | 131.9 | 96.5 | 107 | 117.8 | 120 | 100 | 108.6 | 121.7 | 116.6 | 123 | 118.5 |
| Popliteal Index, | 86.5 | 83.8 | 78.9 | 84.9 | 90 | 86 | 78.9 | 70 | 77.7 | 83 | 84 | 86 |
| (i) Popliteal Width at 4 cm., | 38.5 | 34 | 38 | 36.5 | 36 | 36 | 28.5 | 35 | 36 | 33 | 36 | 36 |
| (u) Max. Bicondylar Width, | 74 | 74.5 | 82 | 82 | 84 | 85 | 71 | 69 | 76 | 75 | 79.5 | 78 |
| $u = 100 ; \frac{u}{i \times 100} =$ | 45 | 45.6 | 46 | 44.5 | 48.8 | 46 | 40 | 50.7 | 47 | 44 | 47.7 | 46 |
| Distance of Linea aspera from External Condyle, | 112 | 120 | 104 | 118 | 104 | 94 | 104 | 115 | 98 | 89 | 96 | 87 |
| "mu," | 28 | 28 | 30 | 31 | 32 | 31 | 22.5 | 24.5 | 23 | 23.5 | 33 | 33 |
| "mp," | 29 | 28.5 | 30 | 31 | 32.5 | 31 | 22.5 | 24.3 | 27 | 27.5 | 32 | 31 |
| Distance of Nutrient Foramen from Lower End of Femur, | 111 | 111 | 111 | 111 | 805 | 270 | 111 | 111 | 266 | 111 | 280 | 275 |

FEMUR.

| Race. | Hindoo. | | | | Bengalee. | | Sikh. | | Malay. | | Chinese. | |
|---|-----------|--------|---------------------|-------------|-----------|--------|--------|--------|--------|--------|----------|--------|
| | Skeleton. | | Part of a Skeleton. | | R. | L. | R. | L. | R. | L. | R. | L. |
| | R. | L. | R. | L. | | | | | | | | |
| | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. |
| Collection, | δ | δ | δ | ♀ | δ | δ | δ | δ | δ | δ | δ | δ |
| Sex, | Adult. | Adult. | Adult. | Adolescent. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. |
| Age, | 503 | 504 | 451 | 401 | 475 | 478 | 493 | 493 | 414* | 446 | 410 | 416 |
| Total Oblique Length, | 47 | 47 | 47 | 86 | 47 | 47 | 53 | 52 | 44 | 44 | 46.5 | 47 |
| Diameter of Femoral Head, | | | | | | | | | | | | |
| Diameters of Sub-trochanteric Region— | | | | | | | | | | | | |
| Antero-posterior, | 25 | 24.5 | 20 | 21 | 21 | 21 | 23.5 | 25 | 26 | 21 | 22 | 22 |
| Transverse, | 34 | 32 | 31.5 | 27 | 27 | 28 | 35 | 33 | 27 | 24 | 28 | 27 |
| Platymeric Index, | 73.5 | 76.5 | 63 | 77.7 | 77.7 | 75 | 67 | 75.7 | 96 | 87.5 | 78.5 | 81 |
| Diameters of Middle Region of Shaft— | | | | | | | | | | | | |
| Antero-posterior, | 30 | 32 | 29 | 25 | 26 | 26 | 26.5 | 28 | 26 | 25 | 24 | 24 |
| Transverse, | 29 | 28 | 27 | 24 | 23 | 22.5 | 29 | 28 | 25 | 24 | 25 | 25 |
| Pilastric Index, | 103 | 114 | 107 | 104 | 113 | 115.5 | 91 | 100 | 104 | 104 | 96 | 96 |
| Popliteal Index, | 84 | 85 | 82.8 | 81 | 87 | 87.5 | 76.9 | 79 | 75.7 | 80.6 | 78 | 80 |
| (i) Popliteal Width at 4 cm., | 37.5 | 37 | 35 | 32 | 31 | 32 | 39 | 39 | 33 | 31 | 34.5 | 35 |
| (u) Max. Bicondyloid Width, | 81 | 80 | 81 | 67 | 82 | 80 | 89 | 90 | 76 | 76 | 79 | 80 |
| $u=100; \frac{i \times 100}{u} = .$ | 46 | 46 | 43 | 47.7 | 87.8 | 40 | 43.8 | 43 | 43 | 40.7 | 43.6 | 43.7 |
| Distance of Linea aspera from External Condyle, | 95 | 105 | 92 | 100 | 120 | 120 | 115 | 123 | 87 | 105 | 102 | 100 |
| “mn,” | 31 | 31 | 30 | 26 | 28.5 | 29 | 30 | 32 | 27 | 28 | 29 | 29 |
| “mp,” | 31.5 | 31.5 | 29 | 26 | 27 | 28 | 80 | 81 | 25 | 25 | 27 | 28 |
| Distance of Nutrient Foramen from Lower End of Femur, | 266 | 198 | 205 | 114 | 148 | 800 | 133 | 188 | 188 | 198 | 270 | 188 |

* United fracture in its Upper Third.

FEMUR.

| Race. | Laplandera. | | | | Eekimo. | | | | Saurisford, Melita, Manitoba. | |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-------------------------------------|-------|
| | R. | | L. | | R. | | L. | | R. | L. |
| | U.A.M. ♂ Adult. | U.A.M. ♀ Adult. | U.A.M. ♂ Adult. | U.A.M. ♀ Adult. | U.A.M. ♂ Adult. | U.A.M. ♀ Adult. | U.A.M. ♂ Adult. | U.A.M. ♀ Adult. | | |
| Collection, | 408 | 361 | 401 | 361 | 429 | 418 | 433 | 422 | 473 | 451 |
| Sex, | 42 | 39 | 42 | 39 | 46 | 41 | 46 | 40 | .. | 50 |
| Region— | | | | | | | | | | |
| Antero-posterior, | 22 | 19 | 31 | 19 | 28 | 26 | 27 | 26 | 29 | 30 |
| Transverse, | 26 | 23 | 26 | 23 | 31 | 29 | 31 | 30 | 35 | 33 |
| Pilastic Index, | 84.6 | 67.8 | 80.7 | 67.8 | 90.3 | 89.6 | 87 | 86.6 | 82.8 | 78.9 |
| Popliteal Index, | 26 | 23 | 26 | 23 | 32 | 30 | 30.5 | 29.5 | 34.5 | 32 |
| (i) Popliteal Width at 4 cm., | 23 | 22 | 23.5 | 22 | 26 | 25 | 27 | 25 | 30 | 30.5 |
| (u) Max. Bicondylloid Width, | 113 | 100 | 106 | 104.5 | 123 | 120 | 118.9 | 118 | 116 | 104.9 |
| u = 100; $\frac{1}{2} \times 100$ = | 71 | 70 | 71 | 70 | 76 | 73 | 76.9 | 73 | 73 | 80.9 |
| Distance of Linea aspera from External | 35 | 32 | 35 | 32 | 40 | 38 | 39 | 38 | 47 | 42 |
| Condyle, | 79 | 66 | 79 | 64 | 82 | 69.5 | 81 | 70 | .. | 89 |
| "mn," | 44 | 43 | 44 | 50 | 48.7 | 54.6 | 43 | 54 | .. | 47 |
| "mp," | 74 | 86 | 72 | 81 | 72 | 102 | 77 | 100 | 94 | 100 |
| Distance of Nutrient Foramen from Lower | 26 | 23 | 25 | 21.5 | 30.5 | 31 | 29 | 31 | 36 | 34 |
| End of Femur, | 25 | 23 | 24.5 | 23.5 | 30.5 | 30 | 30 | 30 | 34.5 | 34 |
| | 235 | 205 | 176 | 222 | 144 | 213 | 225 | 247 | 270 | 265 |

FEMUR.

| Race. | Found in an old Roman wall during the progress of a railway cutting at Leicester. | | | | | | | | | |
|---|---|-------------|-------------|-------------|---------------|-------------|-------------|-------------|-------------|---------------|
| | R. | R. | R. | R. | R. | R. | L. | L. | L. | L. |
| | A. | B. | C. | D.* | E. | F.* | G. | H. | I. | L. |
| Collection, | U.A.M. ♂ | U.A.M. ♀ | U.A.M. ♂ | U.A.M. ♂ | U.A.M. ... | U.A.M. ♂ | U.A.M. ♂ | U.A.M. ♂ | U.A.M. ♂ | U.A.M. ... |
| Sex, | 449 | 438 | 445 | 453 | ... | 453 | 444 | ... | ... | ... |
| | 48 | 49 | 42.5 | 50 | ... | 49.5 | 48 | 48 | ... | ... |
| | 23 | 23 | 23 | 23 | ... | 22 | 28 | 24 | ... | ... |
| | 31.8 | 34 | 33 | 36 | ... | 36 | 34 | 31 | ... | ... |
| | 73 | 64.7 | 66.8 | 63.8 | ... | 61 | 67.6 | 77.4 | ... | ... |
| | 26 | 26 | 26 | 26 | ... | 27 | 26 | 27 | ... | ... |
| | 27 | 26 | 25.5 | 30.5 | ... | 29 | 26 | 26.5 | ... | ... |
| | 96 | 96 | 101.9 | 91.8 | ... | 93 | 100 | 101.8 | ... | ... |
| | 68 | 78 | 67.5 | 77.7 | ... | 77 | 79 | ... | ... | 65 |
| | 41 | 37 | 37 | 36 | ... | 37 | 36.5 | ... | ... | 40 |
| | 82 | ... | ... | 83 | ... | 82 | ... | ... | ... | ... |
| | 50 | ... | ... | 43 | ... | 45 | ... | ... | ... | ... |
| | 95 | 97 | 112 | 85 | 87 | 85 | 100 | ... | ... | 106 |
| | 30 | 30 | 27 | 30 | 23 | 30 | 30 | ... | ... | 27 |
| | 28 | 29 | 26 | 28 | 26 | 28.5 | 29 | ... | ... | 26 |
| Distance of Nutrient Foramen from Lower End of Femur, | 242 | 258 | 268 | 443 | 233 | 282 | 267 | ... | ... | ... |

* Evidently a "pair."

FEMUR.

British. Collected from Dissecting-Room.

| | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|--------|--------|--------|--------|--------|--------|--------|
| | R. | L. | L. | L. | L. | R. | R. |
| Anatomy Department, University of Edinburgh | | | | | | | |
| ult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. |
| 7 | 422 | 436 | 457 | 427 | 449 | 446 | 482 |
| 3 | 41 | 47 | 41 | ... | 53 | 50 | ... |
| 7 | 25 | 23 | 25 | 27 | 29 | 31 | 27 |
| 8 | 32 | 33 | 33 | 29 | 36 | 31 | 33 |
| 5 | 78 | 65 | 75.7 | 93 | 90.5 | 100 | 81.8 |
| 1 | 29 | 34 | 29 | 29 | 31 | 32 | 30 |
| 7 | 26 | 26 | 27 | 28 | 30 | 28.5 | 27 |
| 6.8 | 111.5 | 130.7 | 107 | 111.5 | 103 | 112 | 111 |
| 6.4 | 83 | 88.5 | 77 | 83.5 | 84.5 | 86 | 78 |
| 5 | 86 | 85 | 44 | 86 | 42 | 40 | 41 |
| 5 | 77 | ... | 83.1 | ... | 93 | 87 | ... |
| 5 | 46.7 | ... | 54 | ... | 45 | 45.9 | ... |
| 3 | 70 | 75 | 110 | 86 | 110 | 82 | 95 |
| 5 | 81 | 80 | 82 | 80 | 84.5 | 85 | 93 |
| 3 | 90 | 81 | 84 | 81 | 85.5 | 84.5 | 82 |
| 5 | 258 | 225 | 267 | 255 | 174 | 267 | 174 |

FEMUR.

British (continued). Collected from Dissecting-Room.

| 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|--|--------|--------|--------|--------|--------|--------------|--------|--------|--------|
| L. | R. | L. | R. | R. | R. | R. | L. | R. | R. |
| Anatomy Department, University of Edinburgh. | | | | | | | | | |
| ♂ | ♂ | ♂ | ♂ | ♀ | ♂ | ♂ | ♂ | ♂ | ♂ |
| Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. | Adult. |
| 448 | 429 | 415 | 483 | 387 | 440 | ... | 468 | 430 | 410 |
| 46 | 42 | 41 | 53 | 39 | ... | 42 | 49 | 47 | 40 |
| 28 | 25 | 25 | 27 | 28 | 25 | 23 | 28 | 27 | 23 |
| 29 | 28 | 28 | 36 | 31 | 28 | 31 | 32 | 29 | 28 |
| 96.5 | 89 | 89 | 75 | 90.3 | 89 | 74 | 87.7 | 93 | 83 |
| 31.5 | 29 | 27 | 27 | 24 | 26 | 29 | 31 | 30 | 26 |
| 25 | 27 | 25 | 31.5 | 26 | 25 | 28 | 27 | 25 | 23 |
| 128 | 107 | 108 | 85.7 | 92 | 104 | 103.5 | 114.8 | 120 | 113 |
| 35 | 69 | 76 | 77 | 67.5 | 71.7 | 77.5 | 77 | 80 | 77 |
| 40 | 43 | 36 | 44 | 37 | 39 | 40 | 48 | 40 | 35 |
| 84 | ... | 74 | 87 | 71 | 85 | ... | 82 | ... | 73 |
| 47.6 | ... | 48.6 | 50.5 | 52 | 45.8 | ... | 58.5 | ... | 47.9 |
| 86 | 95 | 76 | 95 | 80 | 103 | 73 | 96 | 95 | 110 |
| 34 | 31 | 31.5 | 35 | 26 | 30 | 30 | 39 | 33 | 29 |
| 34 | 29 | 27.5 | 34 | 25 | 23 | 31 | 37 | 32 | 27 |
| 33 | 33 | 33 | 33 | 255 | 33 | none visible | 33 | 33 | 33 |

R

Collection, .
Sex, .
Age, .
m .

Transverse, .
Pilastric Index, .
Popliteal Index, .
(s) Popliteal Width
(u) Max. Bicondyle
 $u = 100 ; \frac{u}{t} \times 100 =$

Distance of Linea a
Condyle, .
"mn," .
"mp," .
Distance of Nutri
Lower End of Fe

FEMUR.

| Race. | Gorilla. | | Chimpanzee. | | | | Orang-utan. | | Gibbon (<i>Hylobates syndactylus</i>). | |
|-----------------------|----------|--------|-------------|--------|--------|--------|-------------|--------|---|--------|
| | R. | L. | R. | L. | R. | L. | R. | L. | R. | L. |
| Collection, | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | U.A.M. | Mus. Sci. and Art, Edinr. | |
| Sex, | ♂ | ♂ | ♂ | ♂ | ♂ | ♂ | ♂ | ♂ | Adult. | Adult. |
| | 895 | ... | 298 | 299 | 260 | 261 | 269 | 272 | 2051 | 2051 |
| | 52 | ... | 84 | 34 | 29 | 29 | 37 | 37 | 18.5 | 18.5 |
| | 31 | 32 | 20 | 20.6 | 19 | 19 | 18 | 18 | 11.8 | 11.8 |
| | 88.5 | 88 | 28 | 27 | 25 | 25 | 28 | 25 | 13 | 13 |
| | 80.5 | 84 | 71 | 75.9 | 76 | 76 | 78 | 72 | 86.9 | 88 |
| | 30 | 32 | 21 | 21 | 19 | 19.5 | 18.5 | 18 | 11 | 11.5 |
| | 41 | 39 | 27 | 27 | 23.5 | 24 | 24 | 23 | 12 | 12.5 |
| | 73 | 82 | 77.7 | 77.7 | 80.8 | 81 | 77 | 78 | 91.6 | 92 |
| | 51.7 | 50.9 | 75 | 76 | 79 | 79 | 67.8 | 67.8 | 81.5 | 88 |
| | 58 | 55 | 28 | 28 | 24 | 24 | 28 | 28 | 13.5 | 13 |
| | 101 | 101 | 63 | 63 | 56 | 57 | 61 | 61 | 12 | 12 |
| | 57 | 54 | 44 | 44 | 42.8 | 42 | 45.9 | 45.9 | 32.5 | 32 |
| | 37 | 34 | 20 | 20 | 18 | 18 | 20 | 20 | 41.5 | 40.8 |
| | 30 | 28 | 21 | 21 | 19 | 19 | 19 | 19 | 36.9 | 37.5 |
| | 190 | 220 | 157 | 173 | 125 | 145 | ... | ... | 11.5 | 12 |
| | 394 | 399 | 297 | 297 | 256 | 257.5 | 249 | 250 | 12 | 12 |
| | | | | | | | | | 11 | 11.5 |
| | | | | | | | | | 12 | 12.8 |
| | | | | | | | | | ... | ... |
| | | | | | | | | | ... | ... |

Region—

Transverse,

Platymetric Index,

Diameters of Middle Region of Shaft—

Antero-posterior,

Transverse,

Pilastric Index,

Popliteal Index,

(c) Popliteal Width at 4 cm.,

(u) Max. Bicondylloid Width,

 $u = 100 ; \frac{t \times 100}{u} =$

Distance of Linea aspera from External Condyle,

"mn,"

"mp,"

Distance of Nutrient Foramen from Lower End of

Femur,

Condylotrochanteric Length,

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TABLE OF AVERAGES (both Sexes included).

| Race. | Maori. | Australian. | Andaman. | Negro. | Hindoo. | Laplander. | Eskimo. | Sandwich Islander (all females). | British (Modern). | British (Ancient, from near Roman Wall). | Chimpanzee. | Gibbon. |
|---|--------|-------------|----------|--------|---------|------------|---------|--|----------------------|--|-------------|---------|
| No. of bones, | 15 | 14 | 12 | 9 | 6 | 4 | 4 | 5 | 42 | 6 | 4 | 2 |
| Oblique length of femur, | 439.5 | 458.7 | 375.1 | 459.6 | 453.5 | 380.5 | 425.5 | 404 | 459 | 447.3 | 279.5 | 205 ? |
| No. of bones, | 13 | 14 | 12 | 9 | 6 | 4 | 4 | 5 | 39 | 7 | 4 | 2 |
| Diam. of head of femur, | 44.7 | 42.5 | 36.1 | 48.8 | 43.5 | 40.3 | 48.2 | 39 | 47.6 | 47.8 | 31.5 | 18.5 |
| No. of bones, | 11 | 14 | 11 | 9 | 6 | 4 | 4 | 4 | 35 | 3 | 4 | 2 |
| Max. Bicond. diam., | 78.2 | 75 | 66 | 77.5 | 75.8 | 69.5 | 75.6 | 71.5 | 88.3 | 82.3 | 60.5 | 32.2 |
| Proportion of length of femur to diam. of head, | 9.8 | 10.7 | 10.3 | 10.4 | 10.8 | 9.4 | 9.8 | 10.3 | 9.6 | 9.8 | 8.8 | 11 |
| Proportion of length of femur to Max. Bicond. diam., | 5.6 | 6.1 | 5.6 | 5.9 | 5.9 | 5.4 | 5.6 | 5.6 | 5.5 | 5.4 | 4.6 | 6.3 |
| Proportion of Max. Bicond. diam. to diam. of head, | 1.7 | 1.7 | 1.8 | 1.7 | 1.7 | 1.7 | 1.7 | 1.9 | 1.7 | 1.7 | 1.9 | 1.7 |

Proportion of Max. Bicondylloid diam. to diam. of head, 1.7 in Bengalee, Sikh, Malay, Chinese, Bushman, Egyptian, and Guanche femora observed by me. In one Gorilla femur, 1.9.

TABLE of Average Indices. (Both Sexes included.)

| Race. | Maori. | Maori. | Andaman. | Negro. | Illindoo. | Laplander. | Kakima. | Witch Islander. | Yah (modern). | Yah (found Museum Wall). | Kaffir. | Ureole. |
|--------------------|--------|--------|----------|--------|-----------|------------|---------|-----------------|---------------|-----------------------------|---------|---------|
| No. of bones. | 14 | 14 | 13 | 9 | 6 | 4 | 4 | 5 | 7 | 43 | 2 | 2 |
| Platymetric Index. | 63.6 | 82.2 | 78 | 77.7 | 72.5 | 75.7 | 88.3 | 65.1 | 77.7 | 51.5 | 77.6 | 86.6 |
| No. of bones. | 13 | 14 | 12 | 9 | 6 | 4 | 4 | 5 | 8 | 43 | 2 | 2 |
| Pilastric Index. | 110.1 | 122.2 | 115.49 | 114.5 | 107.9 | 105.8 | 118.4 | 112.6 | 96.7 | 170.3 | 125.6 | 129.7 |
| No. of bones. | 13 | 14 | 12 | 9 | 6 | 4 | 4 | 5 | 8 | 43 | 2 | 2 |
| Popliteal Index. | 77.5 | 85.3 | 77.3 | 81.8 | 82.8 | 70.9 | 77.6 | 73.5 | 73.5 | 79.1 | 82.5 | 85 |

| Race. | Dongasee. | Siab. | Malay. | Chinese. | Mantoba. | Bushman. | Egypt. | Guascha. | Chilpanasco. | Orilla. | Orange-stan. | Gilboa. |
|--------------------|-----------|-------|--------|----------|----------|----------|--------|----------|--------------|---------|--------------|---|
| No. of bones. | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 4 | 2 | 2 | 2 |
| Platymetric Index. | 76.3 | 71.3 | ... | 79.7 | 80.8 | 86.2 | 71 | 70.7 | 74.7 | 82.2 | 75 | 82.4 |
| No. of bones. | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 4 | 2 | 2 | 2 |
| Pilastric Index. | 114.3 | 96.3 | 104 | 96 | 119.9 | 119.3 | 93.7 | 115 | 79.3 | 77.5 | 77.5 | 91.8 |
| No. of bones. | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 4 | 2 | 2 | 2 |
| Popliteal Index. | 87.2 | 77.9 | 78.1 | 79 | 76.9 | 81 | 73 | 80.4 | 77 | 51.3 | 7.86 | { at 2 cm. 85.7 at 4 cm. 101.2 } |

ON THE SESAMOID BONES OF THE HAND: A SKIAGRAPHIC CONFIRMATION OF THE WORK DONE BY PFITZNER. By EDWARD FAWCETT, M.B. Edin., *Professor of Anatomy, University College, Bristol.*

"THE sesamoid bones were quite well known to the ancient anatomists; and Soemerring, in his osteology, has given us a good description of them.

"In our time they have been carefully studied by Gillette in 1874; by Aeby in 1875; and by Retterer in 1884. Quite recently—in 1892—their study was revived by Pfitzner, who has published on this subject in the *Morphologische Arbeiten de Schwalbe* a voluminous memoir based on the minute examination of 388 hands and of 385 feet." ¹

Through the kindness of Mr Chattock, Professor of Physics in University College, who has shown the greatest possible interest in the subject, I have been able to examine the hands of thirty-eight of my own students and of three of his by means of skiagraphy. The results exceeded in every way my fondest hopes. Not only were sesamoid bones clearly portrayed, but the cancellous tissue of the various bones was depicted in a delightfully clear manner.

Before stating what the actual results arrived at concerning the position and number of the sesamoid bones were, let me quote from Testut's *Anatomy* what is there mentioned with regard to them; and, in doing so, let me at the same time point out that the statements made in the work in question are based on the conclusions arrived at by Pfitzner. Testut ² states that the peri-articular sesamoids of the hand are all situated on the palmar face of the joints, *i.e.*, on the side of flexion; that they are met with exclusively in the neighbourhood of the metacarpophalangeal and interphalangeal articulations; that they are very variable in form, volume, and number; that their number varies from two to seven for each hand; that two are constant, *viz.*, those which correspond with the metacarpophalangeal articula-

¹ Testut, vol. i. fascic. i. page 343.

² *Traité d'Anatomie Humaine*, vol. i. fascic. i. page 343 *et seq.*

tion of the thumb; that the others are not so constant, only appearing in certain subjects; that these are in order of frequency those of the metacarpo-phalangeal articulations of the index and the little finger, that of the interphalangeal articulation of the thumb, those of the metacarpo-phalangeal articulations, and the interphalangeal of the other digits.

The *metacarpo-phalangeal sesamoids of the thumb* are two in number—one radial, the other ulnar.

The *interphalangeal sesamoid of the thumb* is situated on the flexor aspect of the interphalangeal joint, in the thickness of the capsular ligament of that joint.

The *metacarpo-phalangeal sesamoids of the index and fifth digit* are placed, as their name indicates, in the neighbourhood of these articulations, and always on the flexor aspect.

Typically, there are two sesamoids for each joint, but this condition is rare: most often one only exists for each, viz., a radial one for the index, and an ulnar for the little finger.

The *metacarpo-phalangeal sesamoids of the medius and ring finger* are relatively very rare; only one is found in each case,—at least in man. Pfitzner in 388 hands has only seen the ulnar of the ring finger and the radial of the middle.

The *sesamoids of the distal interphalangeal joints* are extremely rare. Pfitzner has only observed one situated on the index.

Let us now see how far these results may be confirmed by skiagraphy. As has been said before, 38 hands were examined.

In the *metacarpo-phalangeal articulation of the thumb* two sesamoids were found in every case, and they varied much in size, sometimes being very large.

In the *interphalangeal joint of the thumb* a single sesamoid was present 26 times, that is, in $68\frac{1}{2}$ per cent.

In the *metacarpo-phalangeal joint of the index* a single radial sesamoid was found 21 times in 38 hands—roughly speaking, 55.2 per cent. This sesamoid, when well developed, has its long axis placed in the long axis of the digit, hence it is oval in shape. In one case it was large and circular in outline.

It lies under that part of the head of the metacarpal which is ventral to the notch for the radial lateral ligament of the joint. In one case, however, this sesamoid was placed further forward than usual, and projected for a third of its extent beyond the

head. In all cases it was the radial sesamoid that was seen, not one hand showing the ulnar.

The *distal interphalangeal joint of the index* in no case showed any sign of a sesamoid. (Pfitzner only saw it once in 388 hands.)

The *metacarpo-phalangeal sesamoid of the little finger* was present in 27 of the 38 hands examined, *i.e.*, in 71 per cent.

In 2 cases there were two sesamoids present in this joint, *viz.*, a large ulnar and a small radial.

When one sesamoid is found, it lies usually under the ulnar half of the head of the metacarpal bone.

In 1 case it projected forwards beyond the head, as also did the indicial sesamoid of the same hand.

It seems, from the specimens I have examined, that the indicial sesamoid is larger than the one of the little finger in the majority of cases: there are, however, exceptions.

No sesamoid was observed in the ring and middle fingers.

It will be seen that these results correspond very closely with those of Pfitzner, and they were much more easily obtained; in fact, the ease with which they were obtained speaks volumes for the industry of Pfitzner, who, of course, had to dissect out these bones. These results only differ when applied to the relative frequency of the interphalangeal sesamoid of the thumb. Pfitzner places this sesamoid behind those of the little finger and the index. In my results, it comes between those of the index and little fingers. Thus, in little finger a sesamoid occurred in 71 per cent., in the index in 55·2 per cent., in the interphalangeal joint of the thumb in 68·5 per cent.

| | | |
|-----------------------------------|------|-----------|
| Little finger, | 71 | per cent. |
| Thumb (interphalangeal) | 68·5 | „ |
| Index, | 55·2 | „ |

This arrangement, I venture to think, will be found to be the correct one.

I found it true of first 15 hands I examined, and it was equally true of the next 15.

I confess I do not understand why the little finger should show a sesamoid more frequently than the index, unless it is due to the fact that this finger possesses short special muscles such as are found in the thumb.

I have not found that *age* has any special bearing on the size or number of these bones, for one of the poorest examples occurred in a student aged 40, and one of the best, with the largest sesamoids, in one aged 17.

Then, again, muscular strength seems to have, at all events in the cases I have examined, no practical influence on size or number of sesamoids, certainly not on number, because in that respect the number is as great in females as in males, and in the left hand as in the right; and I have reason to suspect that great muscular strength is not necessarily associated with great size of the sesamoids, because in one case, that of an exceptionally powerful student (muscularly), the sesamoids were small, whereas in a weak student (generally) they were large.

These are points which, however, will bear further examination. It would be absurd to base any definite conclusions as to influence on thirty-eight cases; but one can justly from this number draw some conclusions as to the occurrence of these bones, and I have done so here, because our own text-books say very little about them.

"Quain," for instance, vol. ii. pt. i. p. 105, says:—"A pair of sesamoid bones is placed in the palmar wall of the metacarpo-phalangeal articulation of the thumb; and similar nodules, single or double, are sometimes found in the corresponding joint of one or more of the other fingers, most frequently of the index and little fingers."

"Macalister," p. 159, mentions only the sesamoids of the metacarpo-phalangeal joint of the thumb.¹

"Holden," p. 337, 7th edition, describes two at the metacarpo-phalangeal of the thumb, and says—"We rarely find any in the fingers."

"Wilson"—last edition, edited by Clark—is the only book alluding to the greater frequency in the little finger.

"Morris" says nothing about them under Osteology, but refers to some of them cursorily under Arthrology.

In the thirty-eight hands I have examined I have never found sesamoids in connection with the ring finger nor the medius, nor have I seen the inter-phalangeal of the index. It is evident that they are rare.

¹ Since writing the above, I observe that "Macalister," page 162, says, "always in the thumb, and sometimes on the other fingers, especially on the inside of the little finger, the fibro-cartilage ossifies into a sesamoid bone receiving the insertion of short muscles." This statement is made only of metacarpo-phalangeal joints.

It is obvious that the figures I have given can only be of relative value, because the number examined is small—a tenth of the number examined by Pfitzner; but they suffice to call greater attention to his work than seems to have been given to it, and to the fact that these bones do exist more frequently than is generally supposed; they also demonstrate the value of Skiagraphy in another branch of Medical Science.

In conclusion, let me again express my indebtedness to the kind enthusiastic help given by my colleague Professor Chattock, and his assistant, Mr L. N. Tyack.

Notices of New Books.

Handbuch der Gewebelehre des Menschen. Von A. KÖLLIKER, Sechste umgearbeitete Auflage. Zweiter Band, Zweite Hälfte. Leipzig : W. Engelmann, 1896.

WE offer our congratulations to Professor Kölliker on the completion of the second volume of the sixth edition of his famous Handbook on the minute structure of the tissues and organs of the body ; a work which, since the publication of the first edition in 1852, has been one of the best systematic treatises on histology in the hands both of teachers and students. Each successive edition has embodied the results of the continual improvement in the methods of microscopic research and observation. For the Nestor of European teachers, after more than fifty years of constant work, to have brought up to date in this edition our knowledge of the Nervous System as regards the labours of others, and to have added materially to that knowledge by numerous new and original observations of his own, testifies to his intellectual vigour, and to his enduring love of his favourite science.

In the first part of this volume, published in 1893, Kölliker gave an account of the nerve tissues, and of the structure of the spinal cord, medulla oblongata and pons, the origins of the cranial nerves, and the structure of the cerebellum. In the present part he describes the divisions of the encephalon which lie above the pons and cerebellum, together with their membranous envelopes and the sympathetic nervous system. In no other text-book with which we are acquainted is the complex structure of the brain described with so much fulness of detail, and illustrated with such admirably clear sections. In the preparation of these sections the author has been greatly assisted by Herr P. Hofmann, and the methods of Golgi and Weigert have been principally employed. About 500 figures are intercalated in the text of this volume, all of which, with eight exceptions, are original. They have been drawn by Herr L. Stierhof, and the author, in referring to them, testifies to their adherence to nature, and without interference on his part. The author very properly claims for them a value as close transcripts of the original sections, and as having the importance of documents at first hand. No teacher of anatomy, who wishes to present to his students an up-to-date description of cerebral anatomy, can dispense with this volume of Kölliker's Handbuch.

Morphology of the Cerebral Convolution, with special reference to the Order of Primates. By ANDREW J. PARKER, M.D., Philadelphia Academy of Natural Sciences, 1896.

THIS memoir has been published in the *Journal of the Academy of Natural Sciences of Philadelphia*, new series, vol. x. part 3. It extends to more than 100 pages royal quarto, and is illustrated with 14 large plates and several figures in the text. Owing to the death of the author in 1892, the memoir has not had the advantage of his final revision when in type, and has appeared under the auspices of the Publication Committee of the Academy. The author gives a detailed description of the lobes, convolutions, and fissures of the cerebrum. He recognises five classes of fissures:—

1. Fundamental primary or typical, *e.g.*, Sylvian, mesial arched, calcarine, callosal, and hippocampal.

2. Secondary, which give special character to the type of convolutionary configuration, *e.g.*, three occipito-frontal and three occipito-temporal.

3. Sulci, or vegetative repetitions of secondary fissures, which increase the complexity of the cerebral surface.

4. Sulculi, which give special characteristics to particular groups of brains, and are usually repetitions of sulci, or small and apparently irregular fissures.

5. Rami, constant branches of fissures or sulci. He explains the formation of the fissures by the interaction of two set of forces, *viz.*, the growth forces of the expanding brain, combined with and modified by the resisting forces due to the pressure of the bony environment.

The Development of the Branches of the Fifth Cranial Nerve in Man. By A. FRANCIS DIXON, B.A., M.B., Royal Dublin Society, Dublin, 1896.

THE author has investigated the development of the 5th cranial nerve in the human embryo, and has verified his observations by the study of a number of embryo rats. The human embryos ranged in age from four weeks to the eight week. The following method of investigation was employed. The sections through the head of the embryo were enlarged 25 or 50 times in drawings made with the camera-lucida, traced on to glass plates, and covered by a transparent varnish. When the plates were placed in order of the sections, one in front of the other, a model of the head, with its vessels, nerves, etc., 25 or 50 times enlarged, resulted. The most important conclusions drawn from the research are as follows:—A single undivided Gasserian ganglion gives rise to the three divisions of the 5th; before the ophthalmic is present a cellular cord stretches from the ganglion and

occupies the place of the future nerve; axis cylinder processes grow out from the cells of the ganglion into this cord, and in this manner the ophthalmic is formed; with the increase in number of the processes the cells of the original cord become fewer, and are disposed around the developing nerve; the first formed ophthalmic trunk corresponds to the nasal nerve, the frontal is formed later, and all the important branches are represented in the beginning of the 6th week. The ciliary ganglion appears at the same time, and in the 8th week has the adult relations; in no sense is it the homologue of a spinal ganglion. The superior maxillary is differentiated at the 4th week, and all the important branches are present in the 7th week. Meckel's ganglion is seen early in the 6th week, when it is closely connected with the otic ganglion. All the important branches of the inferior maxillary are present early in the 6th week, when the otic and submaxillary ganglia are also present. The inferior dental is first formed, then the lingual nerve. The chorda tympani and Vidian are branches of the facial, and are not developed from the 5th. Jacobson's nerve is derived from the glosso-pharyngeal. It is not proved that the cells of the accessory ganglion of the 5th are derived directly from the cells of the Gasserian ganglion. The sympathetic in relation with the carotid artery in the adult is represented in the embryo by fibres chiefly derived from the trunk ganglion of the vagus nerve.

The Development of the Müllerian Duct of Amphibians. By GREGG WILSON, M.A., B.Sc. Edinburgh: R. Grant & Son, 1896.

THIS research was conducted on the embryos of *Rana esculenta*, *Triton alpestris*, *Salamandra atra* and *maculosa*, Axolotl and Desmognathus, more especially on Axolotl and *S. atra*. The author was induced to undertake the investigation owing to the diverse statements made by previous inquirers, and he precedes the description of his own observations by an analysis of the literature of the subject. He has found Axolotl peculiarly instructive, as in it the pronephros and segmental duct persist during the early stages of formation of the Müllerian duct. He draws the conclusion, 1st, that the anterior end of the Müllerian duct is formed from the thickened epithelium plate that spreads from the nephrostomes over the whole surface of the pronephros and beyond it; 2nd, that the rod of cells that passes backwards along the segmental duct, and which, later, becomes the Müllerian duct, arises from a prolongation of this epithelial plate. In no specimen has he seen any communication between the segmental duct and the Anlage of the Müllerian duct, but the duct-anlage always ended in the epithelium, and the thickened epithelium is the first stage in the development of the posterior end of the duct. The memoir is printed in the *Transactions of the Royal Society of Edinburgh*, vol. xxxviii., 1896.

Ueber Schädel-Masken aus Neu-Britannien besonders eine mit einer Kopfverletzung. Von MAX BARTELS. Berlin: D. Reimer, 1896.

SOME years ago one of the Editors described and figured in this *Journal* (xiv. p. 475, 1880) two masks from New Britain or New Ireland, islands situated to the north and east of New Guinea. Since then additional specimens of masks have been recorded, and the subject discussed by Virchow, P. S. Abraham (*Proc. Roy. Irish Acad.*, 1881), Schmeltz and Krause, Andree, Giglioli, Finsch, Mayer, Uhle, etc. In the memoir now under consideration, Max Bartels has analysed the previously recorded specimens (except Abraham's, with which he does not seem to have been acquainted), and has given the results of his own observations. Forty-one examples are known to him—15 from the descriptions and figures of other anthropologists, and 26 which he has personally examined; of the latter, 13 are in the Grassi-Museum in Leipzig and 12 in the Royal Museum of Ethnography in Berlin, whilst one specimen has been given to himself. Turner, Giglioli, and some other authors had recognised two groups of masks, but Bartels considers that there is also a third group. Of the 41 masks, 28 were in the first, 7 in the second, and 6 in the third group. In Bartels' own specimen the frontal bone was defective at the left eminence, probably due to the weapon which had been the cause of death.

A Revised Description of the Dorsal Interosseous Muscles of the Human Hand. By DAVID HEPBURN, M.D. Edinburgh: R. Grant & Son, 1896.

IN addition to revising the current description of the interosseous muscles of the human hand, the author makes suggestions for a new nomenclature of the palmar interossei, and gives observations on the corresponding muscles in Anthropoid Apes. As is well known, a dorsal interosseous muscle, when seen on the dorsum of the hand, has a bipennate arrangement, but the author points out that when dissected on its palmar aspect many longitudinal fibres may be seen distinct from the bipennate arrangement of fibres, but having a common insertion with them into the first phalanx. The longitudinal fibres arise from the palmar aspects and radial or ulnar side, as the case may be, of the lateral surface of the metacarpal bone. This arrangement he regards as normal; and the cases which have been described as increase in the number of palmar interossei are only examples of unusual development of these longitudinal fibres. Hepburn considers that the present use of 'palmar interosseous' should be discarded, and that a general term 'short flexors of digits' should be employed. The short flexor of each digit, except pollex and minimus, would consist of the muscle now known as palmar inter-

osseous, and of either the radial or ulnar longitudinal fibres, as the case may be, associated with the insertion of the dorsal interosseous. To give an illustration, the *M. flexor brevis indicis* has an ulnar head (1st palmar interosseous) and a radial head consisting of the longitudinal fibres associated with the abductor indicis, and they are inserted into opposite sides of the base of the 1st phalanx of the index digit; the *M. fl. brevis minimi digiti* has a radial head (3rd palmar interosseous) and an ulnar head—the muscle which now appropriates the name; they are inserted into opposite sides of the base of the 1st phalanx of the minimus. Each abductor in the dorsal stratum is intimately associated at its insertion with one of the divisions of a short flexor. Three nerve twigs pass to each interosseous space for the three muscular divisions which it contains. The author concludes with a review of the corresponding muscular arrangements in the hands of apes. The memoir is printed in the *Transactions of the Royal Society of Edinburgh*, 1896.

Sezione Mediana Verticale antero-posteriore mediante congelamento di cadavere al sesto mese di gestazione. Descrizione fatta dal Dr GIUSEPPE SOFFIANTINI. Hoepli, Milan, 1891.

THIS large folio volume, containing a description, with six lithographic plates, of a vertical mesial section through the body of a woman in the sixth month of gestation, is of interest, both to the anatomist and gynecologist. The axis of the uterus and its relation to the pelvic brim, axis and outlet; the presentation of the foetus, which in this case is the head; the surface of attachment of the placenta and the origin of the umbilical cord, are displayed in the plates. The text contains both a description of the figures and an account of the observations of previous authors who have investigated the position and relations of the viscera by the aid of frozen sections.

The memoir is one of the publications of the Anatomical Institute of the University of Pavia.

Hand Atlas der Anatomie des Menschen, mit Unterstützung von Wilhelm His, bearbeitet von Werner Spalteholz. Leipzig, Hirzel. Erster Band, Erste Abtheilung, 1895; Zweite Abtheilung, 1896.

THE first volume, now completed, of this Atlas of Human Anatomy contains a description of the bones and joints, with illustrative figures. The plan of the book is ingenious. In the upper part of each page is a well executed figure of the bone or joint, immediately below which is a terse description of the object. In the case of those bones which have muscles attached, an outline of the bone is given and the area

of attachment of each muscle is marked out, after the manner so graphically employed by Mr Luther Holden, and subsequently adopted by many descriptive writers. The parts are clearly delineated in the figures, and the student will find the book of great utility. As both the German and Latin or Greek technical terms are employed in the description, any English-speaking student who wishes, without much trouble, to acquire a knowledge of the German equivalents of our technical anatomical terms, can easily do so with this book before him.

Atlas der Topographischen Anatomie des Menschen von Dr KARL VON BARDELEBEN und Dr HEINRICH HABECKEL. Jena: G. Fischer, 1894.

In this Atlas are depicted in coloured figures not only a number of dissections of regions, but numerous sectional views of different parts of the body. The regions selected for illustration are those which have a bearing on medical and surgical practice. Each figure is accompanied by descriptive letterpress, and the terms employed are, as a rule, those recommended by the Nomenclature Commission of the Anatomical Society.

SIR GEORGE MURRAY HUMPHRY died at Cambridge, in his 77th year, on the night of Thursday, 24th September, when the last sheets of this number of the Journal were in the press. It is now thirty years ago since he took the initiative in founding the *Journal of Anatomy and Physiology*. For a number of years he was the acting editor, and contributed many articles on Comparative Anatomy to the early volumes. When the pressure of his various engagements and advancing years led him to resign to one of his colleagues the duties of acting editor, he continued, as one of its conductors, to take a personal interest in its progress, and as late as the last two volumes he published in the Journal papers on Microcephalic and Macrocephalic Crania, and on the Structure of Urinary Calculi. His colleagues in the management of the Journal mourn the loss of one whose determination of character and well balanced judgment were of great service in piloting it through the difficulties of its early career, with whom their personal relations were ever most cordial, and in whom they always found an able and energetic coadjutor.

PLATE I.

FIG. 1.

FIG. 2.

DEVELOPMENT OF CEREBELLUM

PLATE II.

FIG. 3.

FIG. 4.

THE ANATOMICAL TRACT

PLATE III.

FIG. 4.

FIG. 5.

DEVELOPMENT OF OPTIC NERVE

PLATE IV.

FIG. 7.

FIG. 8.

DEVELOPMENT OF GENITAL TRACT.

PLATE V.

FIG. 9.

J. T. MURRAY, DEL.

FIG. 10.

DEVELOPMENT OF GENITAL TRACT.

PLATE VI.

FIG. 11.



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Nº 3.

Photo by D^r T. Reid for G. B. Todd

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ABNORMALITIES OF THE MIDDLE SACRAL ARTERY, AND THEIR MORPHOLOGICAL SIGNIFICANCE. By ALFRED H. YOUNG, M.B., F.R.C.S., &c., *Professor of Anatomy, The Owens College, Manchester.*

INASMUCH as abnormalities usually represent in a permanent form some condition which is normally but a transient stage in the phylogeny or ontogeny of organs, they are not only interesting but also significant, and their value in determining morphological problems is unquestionable.

Some time ago I ventured to suggest, mainly as the result of comparative observations on the termination of the mammalian aorta,¹ that the fusion of the primitive dorsal aortæ ceased at the bifurcation of the single trunk into the iliac vessels, and that the middle sacral artery did not represent a posterior prolongation and fusion of the primitive dorsal aortæ beyond this;² but, on the contrary, was a secondary development, probably formed by the fusion of two vessels arising independently, and constituting simply branches of the primitive trunks. I also pointed out the significance of some of the most common

¹ *Studies in Anatomy from the Anatomical Department of The Owens College*, 1891, vol. i. p. 209.

² This view has recently been adopted by Dr David Hepburn of the University of Edinburgh. He found in the Grey Seal (*Halichærus Grypus*), unlike other Carnivores, that the aorta terminated by bifurcating into common iliac arteries, and that the middle sacral artery arose from the dorsal aspect of the aorta, two inches in front of its bifurcation.

"To my mind," Dr Hepburn proceeds, "this mobility of the point of origin of the middle sacral artery of the Seal, as compared with other Carnivora, suggests the priority of the aortic trunk, and the formation of the middle sacral as a collateral branch rather than the formation of the smaller vessel by fusion of two primitive aortæ"; and he subsequently adds further, "that the comparatively late period at which the tail grows backwards, to a large extent excludes this vessel from being regarded as the direct aortic continuation."—*Journal of Anatomy and Physiology*, vol. xxx., 1896, 498 et seq.

abnormalities of the middle sacral artery ; our knowledge of these abnormalities has, however, been so greatly extended, and is so much more precise now than it was, that I may be permitted to refer to them again.

If the middle sacral artery is truly the morphological continuation of the aorta, its most common abnormalities will in all probability afford some evidence of the fact. One might anticipate, indeed, that anomalies of distribution, such, *e.g.*, as the origin from it of important visceral or parietal 'segmental' branches would not be uncommon ; on the other hand, one would hardly expect to find the middle sacral itself arising from a secondary or segmental branch of its own primitive trunk. Indeed, it would seem impossible that the true continuation of the aorta could vary as regards its origin at all.

As a matter of fact, abnormalities of origin are comparatively frequent, and those of distribution rare.

The mode and place of origin of the middle sacral artery in man in 400 cases—39 of which came under my observation in the dissecting-room of The Owens College—are well recorded in the Report of the Committee of Collective Investigation of the Anatomical Society of Great Britain and Ireland for the year 1891-92.¹

In 322 of the 400 cases examined, the artery arose as a single trunk directly from the aorta, but the point of its origin was not constant. In only one case did it arise just *at* the point of division of the aorta. The origin in the remaining 321 was *above* the bifurcation and from the posterior surface of the aorta, —the exact point of origin being in some few cases "as high as 1 inch, or 25 mm., above the bifurcation of the parent stem."

In 39 cases the middle sacral arose in common with the fourth lumbar arteries, and in all these cases, again, the origin was well above the bifurcation of the aorta. A single case is also mentioned in which the 'sacra media' was similarly associated with the third lumbar arteries.

In 20 cases the middle sacral arose from one of the fourth lumbar arteries, whilst in other 20 cases the origin was from one of the common iliacs.

Mr F. G. Parsons, of St Thomas' Hospital, in one instance

¹ *Journ. of Anat. and Phys.*, vol. xxvii. p. 183.

'was unable to find the slightest trace of a middle sacral artery.'

From this report it is clear that whilst the middle sacral artery is almost invariably present in the human subject, it is not always directly connected with the aorta, but, on the contrary, arises from one of its so-called branches. Further, that when arising directly from the aorta, it does so, almost without exception, above or in front of the bifurcation, and not at it.

Thus the portion of the main systemic trunk intervening between the origin of the middle sacral artery and the terminal bifurcation cannot, strictly speaking, be considered as aorta at all; it is, as I have previously said, rather to be regarded as a common allantoic or iliac stem. In other words, if the middle sacral artery is the true and direct prolongation of the primitive dorsal aorta, surely the continuity must remain unbroken,—the sacral part of the aorta must directly continue caudalwards the abdominal portion, as this latter continues the thoracic portion.

If this is so, obviously any vessels up to the point of origin of the middle sacral must represent part of the primitive dorsal aorta. It is difficult to admit this in the not uncommon cases where the middle sacral artery arises from one of the lumbar vessels.

In short, the explanation of these anomalies of origin is beset with difficulties so long as the middle sacral is looked upon as the morphological continuation of the aorta, whilst they clearly point to the secondary character of this vessel as being a branch merely of the primary trunks.

The branches usually given off by the middle sacral artery consist of small mesial branches from the front of the vessel "which pass into the fold of the mesorectum and ramify upon the posterior surface of the intestine; and others, on each side, which spread out upon the sacrum, and anastomose with the lateral sacral arteries, occasionally sending small offsets into the anterior sacral foramina."¹

If the middle sacral is a true caudal aorta, the mesial branches must be regarded as corresponding to visceral, and the lateral to

¹ *Quain's Anat.*, 10th edition, vol. ii. part ii. p. 469.

intercostal and lumbar somatic branches; but it is at least remarkable that they should have degenerated so much, and that their function should have devolved so largely upon the iliac vessels.

On this point, again, a consideration of the abnormalities of distribution of the middle sacral artery is interesting. They are well epitomised by Professor Thane in *Quain's Anatomy* (*loc. cit.*, p. 469) as follows:—

“It often gives off on each side a considerable branch (*lowest lumbar artery*) which passes backwards on the fifth lumbar vertebra. The middle sacral artery has also been seen to furnish an accessory renal or a middle hæmorrhoidal artery.”

The occurrence of parietal and visceral branches, as abnormalities even, may undoubtedly be regarded as evidence in favour of the primitive aortic nature of the middle sacral artery, though abnormalities of distribution must, I think, be deemed secondary in importance to those of origin; and the morphological significance of such abnormalities is increased when they frequently recur with a certain degree of uniformity.

The majority of the anomalies of distribution of the middle sacral artery do not occur very often, however, whilst the most common abnormality is of doubtful significance. The lowest lumbar arteries arise in many instances rather in common with the middle sacral than from it, and it is not possible to say which trunk arises from the other, whilst in other cases it is clear that the middle sacral itself arises from one of the lower lumbar.

The occurrence of abnormal visceral branches is rare,—a definite middle hæmorrhoidal, replacing the one arising from the iliac vessel, is almost unknown. Somewhat more common, but still comparatively rare, is the existence of accessory renal branches.

My friend Professor Thane has kindly placed at my disposal some suggestive notes and references relating to this group of abnormalities, from which I take the following cases in which a renal artery arising from, or in common with, the middle sacral has been recorded.

Otto¹ (1830) briefly mentions two cases—in one a right

¹ *Pathol. Anat.*, 1830, p. 312, South's Translation, 1831, p. 305.

renal branch, and in the other a left arising from the middle sacral.

Bonnet¹ (1835) describes a case in which the right kidney, very small, situated in the pelvis, receives its artery from the bifurcation of the aorta, as if, he proceeds, "the middle sacral was transformed into the renal artery." The presence or absence of a true middle sacral, independent of the vessel to the kidney, is not stated, and the author was evidently under the erroneous impression that the middle sacral rises from the bifurcation of the aorta. This case can hardly be accepted as an instance in which the kidney is supplied by the middle sacral.

Barkow² (1850) describes a specimen in which the arteria sacra media gives an offset which divides into right and left inferior renal branches, each of which ascends to its kidney in front of the origin of the common iliac artery.

Struthers³ (1863) showed specimens from two cases at a meeting of the Edinburgh Medical Chirurgical Society, and remarked that "the nature of the arteria sacra media, as the true aorta, in contrast with the iliacs, which, notwithstanding their size in man, were of the nature of branches, explained the fact that in both the cases the renal artery furnished by the middle sacral, instead of passing more directly behind, advanced and passed across in front of the common iliac, just as a supplementary or normal renal from the aorta was in front of a lumbar artery."

Macalister⁴ (1883) records a case in his paper on "multiple renal arteries," and also notes that the abnormal vessel crosses the left common iliac artery.

Londe⁵ (1890) describes a renal branch arising in common with the middle sacral.

Possibly other cases have been recorded, but undoubtedly the abnormality is not common.

¹ "Anomalies des Uretères et du Rein," *Bulletins de la Société Anatomique de Paris*, Janvier 1835, p. 187.

² *Anat. Abhandl.*, 1851, p. 32. See also *Anat. Samm.*, Breslau, 1850, No. 1934; and *Angiologische Sammlung*, Erste Abth. Breslau, 1869, p. 8, No. 53.

³ *Edin. Medical Journal*, July 1863, p. 759.

⁴ *Journ. of Anat. and Phys.*, vol. xvii. p. 251.

⁵ *Bull. Soc. Anat. Paris*, 1890, p. 199.

Speaking generally of this group of anomalous visceral branches, it may be pointed out that the existence of a renal vessel arising from the middle sacral artery is very rare, even when the kidney is situated in the pelvis, whilst a renal branch from the common or internal iliac is by no means an uncommon abnormality. It is even rarer to find the middle hæmorrhoidal artery, normally a branch of the internal iliac, taking its origin from the middle sacral; and it is further noteworthy that the spermatic artery, a visceral trunk posterior in position in man to the renal, has not in a single instance, so far as I know, been seen to arise from the middle sacral.

The abnormalities which have been considered, and particularly those of origin, afford, it seems fair to say, valuable corroborative evidence that the middle sacral artery is not the true morphological continuation of the primitive dorsal aortæ, a conclusion which seemed justified by comparative observations on this vessel and on the termination of the mammalian aorta, and which is not incompatible with what is known of its development. The very rare abnormality of a middle sacral dividing into two branches¹ illustrates what is perhaps the best known feature in its development, *e.g.*, that it first appears as a pair of longitudinal vessels which soon fuse into one. Before their appearance, the primitive dorsal aortæ curve over the lateral surface of the posterior end of the intestine, and there is no vestige of a caudal continuation of the aorta. So much at least I was able to record as the result of an examination of mouse embryos; but I could not determine whether the primarily paired middle sacral vessels were offshoots from the primitive dorsal aortæ, or whether their junction with these trunks was secondary.

The observations of Dr F. Hochstetter² on rabbit embryos of 11 days would seem to indicate that the two small arteries which eventually become the middle sacral are from the first connected with the aorta. The primitive double nature of the middle sacral is further shown by its normal and permanent

¹ Meckel (J. F.), *Manual of Anatomy*, Doane's Translation, vol. i. p. 451. Lawrence, Report of Collective Investigation Committee, *Journ. of Anat. and Phys.*, vol. xxvii. p. 185.

² *Morph. Jahrb.*, xvi., 1890, p. 300.

character in the armadillo ¹ (*Dasypus sexcinctus*), where the two vessels remain distinct throughout, and in *Auchenia lama*,² where the vessel arises by a single stem, but divides soon after its origin.

¹ Young, *loc. cit.*, p. 213, plate vii. fig. 6.

² Barkow, *Comparative Morphologie des Menschen und der Menschenähnlichen Thiere*, Vierter Theil, Tab. iv. fig. 2.

ON THE HÆMOLYMPH GLANDS OF SOME VERTEBRATES. By SWALE VINCENT, M.B. (Lond.), *Demonstrator of Physiology and Assistant Lecturer on Histology, Mason College, Birmingham*; and H. SPENCER HARRISON, Student in the Royal College of Science, London, and Mason College, Birmingham. (PLATE VIII.)

(From the Physiological Laboratory, Mason College, Birmingham.)

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INTRODUCTORY.

THE structure of lymphatic glands has long since found its way into all the text-books, but the bodies we are about to describe have not hitherto received the attention they deserve. Although they have been known for a long time to butchers and others, it is only within the last six years that any attention has been paid to their minute anatomy. It is very probable that, when occurring in the regions of the spleen and kidneys, they have often been mistaken for accessory spleens or even accessory suprarenals.

Up to the present, so far as we know, nothing has been said about these structures except in Man and certain Ungulates. We have succeeded in finding them in a rodent (rat) and in

birds (common fowl and turkey), and also bodies closely allied to them in some other animals (dog, and certain fishes).

We shall indicate later on that there are intermediate forms between ordinary lymphatic glands and the bodies which are the subject of this paper; but the important distinction remains, that in lymphatic glands the sinuses contain lymph, while in the other case they contain blood.

The investigation has been pursued in some cases under very difficult conditions. The dissection necessary for the display of the glands had to be carried on in the case of the ox and sheep in the butcher's slaughter-house, and in the case of the horse in the knacker's yard; in the latter instance, particularly, careful dissection was out of the question.

As regards the existence of the glands in the human subject, concerning which previous observers differ, we can only state that we have found them in at least one case, though we have searched in vain in others. We shall make further remarks on this subject when discussing the histology of the glands.

We have decided to retain the name 'hæmolymp glands,' originally given to these structures by W. F. Robertson, since they undoubtedly combine ordinary lymphoid structure with blood-containing sinuses.

Although our description of the glands in the sheep and ox does not differ greatly from those of Robertson and Clarkson, we have made our account as complete as possible, since the original descriptions were published in Medical Journals, and illustrated by wood-cuts of a somewhat unsatisfactory nature. We thought the subject sufficiently important to deserve a re-description, accompanied by plates, in a publication more certain to come into the hands of comparative anatomists and histologists.

We are indebted to Dr Clarkson for references to two of the original papers.

1. BIBLIOGRAPHICAL.

The earliest mention of the hæmolymp glands is contained in a paper by Heneage Gibbs in the *Quart. Journal of Micros. Science* (1884), vol. xxiv. p. 186, "On some Structures found in the connective tissue between the renal artery and vein in the human subject." He appears to have been the first to describe structures

resembling lymphatic glands, but having their sinuses full of blood instead of lymph.

The first detailed description is given by W. F. Robertson in the *Lancet* for 29th Nov. 1890. This observer found them not only in the ox and sheep, but also in the human subject, and gives a very careful description of their anatomy and histology, illustrated by woodcuts. He does not appear to have been aware of Gibbs' observations. He suggests, with due caution, that the bodies are concerned in the formation of red blood disks, and describes the nuclei of certain cells as giving rise to eosinophilous globules, possibly small red cells. He believes that the nuclei of certain multinucleated cells lose their affinity for logwood as they increase in number, and at the same time approach both in staining reaction and in form to small red blood corpuscles.

To the *British Medical Journal* of 25th July 1891 Dr Clarkson contributes a "Report on Hæmal Glands," describing certain glands which are to be found accompanying the renal artery in some herbivora, viz., horse, sheep, and pig. He says, "after microscopical examination, it appears almost certain that they have a very important relation to the formation of the red blood corpuscles." According to him, they do not appear constantly, but are to be found in the great majority of cases. He founds his view as to the blood-forming function upon appearances very different from those which suggested the same thing to Robertson. He observed vacuoles or faintly-staining globules in the substance of certain cells, which he considered were possibly blood corpuscles in process of formation.

In 1896, in *A Text-book of Histology*,¹ Clarkson combines a description of the hæmolymp glands of Robertson and the glands previously described by himself in relation to the renal artery, under the common name of 'hæmal glands,' classifying them in two varieties, but ignores both Gibbs' and Robertson's claims to have found the hæmolymp glands in the human subject. In regard to their function here Clarkson states definitely, "There seems little reason to doubt that they are local centres for the production of blood corpuscles, both red and white."

2. METHODS.

The ox, sheep, pig, and horse have been dissected, as before stated, under great difficulties. But in every case we have taken care that the tissues should be perfectly fresh.

The hæmolymp glands, where found, were placed immediately in hardening fluid, and subsequently treated in different ways. We have found Müller's fluid to give by far the best results. We have also used alcohol, both in the form of methylated spirit to commence with, and in increasing strength, beginning with 30 %. The shrinkage

¹ Bristol : J. Wright & Co., 1896, p. 254.

and distortion caused by methylated spirit rendered this reagent very unsuitable for hardening the glands. We have employed, in addition, formalin, Fol's fluid, and Mann's fluid, with varying results.

After hardening, we have obtained the best preparations by staining in bulk with Ehrlich's hæmatoxylin and eosin, embedding in paraffin, and cutting with the rocking microtome. Others of the glands were stained with picro-carmin, borax-carmin, and alum-cochineal, and similarly cut in paraffin. Again, we have, after hardening, cut some of the glands with the ether freezing microtome, and stained the separate sections in various ways. Finally, we have employed the cover-glass method in several cases.

The results obtained by these various methods have agreed tolerably well.

3. SPECIES EXAMINED.

Mammalia : *Bos taurus*, *Ovis aries*, *Equus caballus*, *Sus domesticus*, *Canis familiaris*, *Felis domestica*, *Mustela furo*, *Lepus cuniculus*, *Cavia cobaya*, *Mus rattus*, *Sciurus vulgaris*, *Mus musculus*, *Talpa europæa*, *Erinaceus europæus*, Catarrhine monkey (species not identified).

Aves : *Anas boschas*, *Anser cinereus*, *Psittacus erithacus*, *Gallus bankiva*, *Columba livia*, *Meleagris gallopavo*.

Amphibia : *Bufo vulgaris*, *Rana temporaria*.

Pisces : *Gadus morrhua*, *Anguilla anguilla*, *Scyllium canicula*, and several other Elasmobranchs, *Cyclopterus lumpus*.

4. GROSS ANATOMY.

MAMMALIA.

We shall describe the anatomy in the sheep and ox together, as there is no important difference between them.

i. *Bos taurus* and *Ovis aries*.

On examining the fat in the subvertebral region, one finds large numbers of blood-red bodies, distributed irregularly on either side of the vertebral column. They are always, as far as we have been able to observe, completely embedded in fat. Immediately after the animal is killed they are easily seen distributed in the adipose tissue, but after some little time, as this becomes opaque, the bodies are not so readily visible. On a cursory inspection, they have somewhat of a resemblance to blood-clots; but in spite of this appearance and

their delicate consistency, closer examination shows them to possess a definite structure. Their colour is that of blood, sometimes arterial, sometimes venous. Whether this is due to more or less exposure to air, or whether it corresponds to some physiological distinction, we cannot say, but the former seems more probable. They are easily cut or ruptured, and a bloody fluid exudes. Their shape is subspherical or oval, occasionally lenticular.

On handling, they convey rather the impression of being sacs filled with blood. In size, they are decidedly larger on an average in the ox than in the sheep. They vary from about 2 mm. to 1.5 cm. in their greatest diameter. Their average size may be roughly stated to be about that of a small pea.

These subvertebral glands extend some distance into the pelvis, and reach along the mesentery almost to the attachment of the intestine, though they are not very numerous in this latter situation. Others are found in the fat surrounding the kidney and in the neighbourhood of the renal vessels. Some of these last have an appearance slightly more resembling that of a lymphatic gland than have those in other situations. Clarkson considers these to be a separate variety, and describes them as being intimately connected with the renal artery. We do not, however, consider it possible to draw a hard and fast line between the two kinds. The peculiarities of typical examples of Clarkson's second variety will, however, be described under the head of Histology.

In the thorax, the glands are found in less number than in the abdomen, occupying in this situation the connective tissue of the mediastina and the fat round the root of the lungs. But they are not constantly present in all these situations. Thus, in one sheep we could find none near the roots of the lungs. The bodies in the thorax are not so large as those in the abdomen.

ii. *Equus caballus*.

So far, the glands of the horse have only been described by Clarkson as occurring in the neighbourhood of the renal artery. No subvertebral glands have been found. We have been able to some extent to verify Clarkson's account of those round the

kidney, but were quite unable to examine the subvertebral region. The glands near the kidney do not appear to be in such intimate association with the renal artery as Clarkson describes. They were not, for the most part, inserted on the blood-vessel, but placed at some distance from it. They appeared as dark red bodies, of various sizes and shapes, the average diameter being about 1·5 cm.

We do not wish to lay too much stress on our observations in the case of the horse, for reasons already stated.

iii. *Mus rattus*.

In the rat, bodies undoubtedly corresponding with the hæmolymp glands of the sheep and ox were found to occur with great constancy, embedded in a peculiar brownish fat in the neighbourhood of the renal artery.

They exhibit the characteristic red colour, but are proportionably much larger than in the sheep.

Their shape is sometimes oval, sometimes lenticular; and the largest measured 3 mm. in its longest diameter. The number varies from one to three; and they are sometimes confined to one side of the body, sometimes found on both sides.

In some few cases, however, no undoubted hæmolymp glands were found, but their place appeared to be taken by compound-looking bodies, to be presently described.

In the fat, in relation to the gastro-splenic omentum, was found a row of three or four small bodies, displaying great difference in colour, some being pale arterial blood-red, others almost colourless. In some cases, also, the bodies were pale, but mottled with blood-red patches. This chain of bodies was found to occur with great constancy.

In some of the specimens of the white rat examined, the hæmolymp glands in the renal region were apparently replaced by pale bodies, mottled like those described above, while in the brown rat large lymphatic glands only were found in this situation.

In one specimen (white rat) several undoubted hæmolymp glands were found in the median and lateral subvertebral regions.

iv. *Canis familiaris*.

No typical hæmolymp glands were found in this animal, but in one specimen examined two large curiously mottled bodies were found on the splenic vein, one at its bifurcation before entering into the substance of the spleen, and another some distance behind this point. These were about 2×1 cm. and 2.5×1.5 cm. respectively. They were lobulated, and in colour partly red and partly pale yellow. Bodies of this character were found in different situations in other individuals, *e.g.*, in the subvertebral sacral region. Their appearance resembles that of the compound bodies already described in the rat, and it will be seen that this resemblance also obtains in their minute anatomy.

In one *rabbit* examined we found a kidney-coloured body, oval in shape, $4 \times 2\frac{1}{2}$ mm., lying in the omentum, connected by a small branch with a large blood-vessel running in this structure. This we took, at first sight, for a hæmolymp gland, but on close examination found that, with the exception of this body, the spleen was unrepresented. Microscopic examination showed this body to have the true spleen structure.

We have not found hæmolymp glands in any rabbit examined, nor have we succeeded in finding them in the following mammals, —ferret, cat, guinea-pig, squirrel, mouse, hedgehog, mole, and monkey.

In the *pig*, no subvertebral bodies were found; but the renal artery was not examined.

v. *Aves*.—*Gallus bankiva*.

In the common fowl, in the fat dorsal to the posterior end of the sternum, in the abdominal cavity, was found a small dark red body, evidently a true hæmolymp gland. It was spherical in shape, and not quite 1 mm. in diameter.

Other similar structures were found in the fat round the stomach and below the rectum, the largest being about 1.5 mm. in diameter. Though small, the appearance of these bodies was unmistakable, their resemblance to those of the ox and sheep rendering their nature quite obvious.

We have found that hæmolymp glands are not invariably present in the fowl.

In a *goose* (*Anser cinereus*) we found a body situated in the gastro-splenic omentum, which, to the naked eye, bore a close resemblance to a hæmolymp gland. We shall remark further on this body when discussing the Histology. We have succeeded in finding small glands in the turkey.

We have failed to find any of the glands in the duck, pigeon, and parrot; also in the frog and toad.

vi. *Pisces*.

We have searched carefully in various species of fishes, both in Teleosts and Elasmobranchs, but we have not found anything which appears, to the naked eye at any rate, comparable to the hæmolymp glands of higher vertebrates, except perhaps in *Cyclopterus lumpus*. (See, however, Histology, below.)

5. HISTOLOGY.

i. *Bos taurus* and *Ovis aries*.

Since, in their minute anatomy, the hæmolymp glands of the ox and sheep are so nearly identical, it will be simpler to include them in a common description.

Examined in section under the microscope, the glands are seen to be invested in a *fibrous capsule* (v. Pl. VIII. figs. 1 and 2, c), which is continuous with the trabecular structure within their substance.

The capsule varies in thickness within very wide limits, and is composed of fibrous tissue, containing some few elastic fibres and elongated nuclei, some of which are evidently those of plain muscle fibres. There are, however, other nuclei of various sizes and shapes, as seen in section; and many show nuclear granules or nucleoli, and occasionally nuclear figures. The elastic fibres are particularly distinct in the ox.

The blood sinus, to be presently described, beneath the capsule, sometimes encroaches upon or excavates the inner half of the fibrous coat. In the bullock, moreover, the capsule is especially loose in texture, and contains many leucocytes between its con-

stituent layers. Blood-vessels occur with comparative frequency, and there are occasional spaces which do not contain blood, presumably belonging to the lymphatic system. Small patches of dark brown pigment are also scattered sparsely throughout the fibrous tissue.

In most sections, immediately external to the capsule, are seen numerous fat-cells belonging to the tissue, in which the organ was embedded (*v.* figs. 1 and 2, *f*). In no instance did we find any fat-cells inside the capsule.

The thickness of the capsule is more uniform in the sheep than in the ox.

Continuous with the substance of the capsule are *fibrous trabeculae* which run into the interior of the gland. These are comparatively insignificant in the sheep, but large and striking in the ox, and resemble those of the spleen. They are sometimes thicker than the capsule itself. In structure they resemble the capsule, and in the larger glands may contain in their substance lymph corpuscles, either solitary, or aggregated to form nodules. Also, occasionally, in the ox, they show small blood sinuses. These trabeculae branch irregularly, and are lost in the substance of the gland.

Immediately within the capsule is a *sinus containing blood*, and extending all round the gland, as seen in section (Pl. VIII. figs. 1 and 2). This *peripheral sinus* is of irregular width, varying from about $\frac{1}{10}$ to $\frac{1}{20}$ the diameter of the gland, and communicates by irregular channels with other sinuses in the interior of the gland. These *central sinuses*, again, communicate freely with each other, and there is no reason to doubt that the blood is able to pass freely from any sinus to any other. Both the peripheral and the central sinuses are lined by a *flat epithelium*, which shows distinctly in most specimens (fig. 2 (5)). This appears to be quite continuous on all parts bounding the sinuses, being reflected over the trabeculae which run through them. In profile, the nuclei of these cells appear as spindle-shaped prominences on the interior of the capsule, and bounding the adenoid portions of the gland. The sinuses, like the corresponding sinuses in a lymphatic gland, are bridged across by an adenoid reticulum. This applies particularly to the peripheral sinus. Some of the smaller central sinuses appear to have no such

reticulum. It consists, where present, of irregular cells, mainly triangular in section, showing a nucleus and nucleolus, with fine branching fibrous processes, communicating with those of neighbouring cells (fig. 2, *r*). In addition to this reticulum there appears to be one of another sort derived from the fibrous tissue of the capsule, and these two communicate with one another.

The sinuses contain for the most part red blood cells, but there are also leucocytes in considerable numbers (figs. 2 and 3, *wh.c.*). As the proportion of the latter is greater than in ordinary blood, it is probable that many of these white cells are derived from the lymphoid tissue described below. We shall refer to this point again in discussing the probable function of the glands.

Both the central and peripheral sinuses contain masses of altered pigment, probably some form of hæmatin. In some instances there are leucocytes containing pigment, apparently in various stages of digestion.

This pigment is also found scattered through the lymphoid portion of the gland. The pigment masses are of various sizes and shapes, and differ in the intensity of coloration, some being quite black, and others pale yellow or orange. Both in the sinuses and the lymphoid tissue there are numerous small granules of pigment (fig. 2 (8)).

That portion of the interior of the gland which is not occupied by blood sinuses consists of lymphoid tissue, resembling that of a lymphatic gland. The amount of space respectively occupied by the sinus and adenoid tissue varies, within very wide limits, in different glands and in different animals. Thus the central sinuses are less extensive in the bullock than in the sheep.

Both in the sheep and ox the distribution of the lymphoid tissue is not perfectly uniform, but it is occasionally aggregated into roundish nodules: this is much more striking in the ox than in the sheep.

There appear to be two distinct forms of lymphoid accumulations: (1) large, irregular, ill-defined follicles, like those of a lymphatic gland, or still more like those of the tonsil; (2) smaller rounded or oval masses, as described by Clarkson and Robertson as looking like Malpighian bodies of the spleen; these are often bounded by a narrow blood sinus, with a reticulum.

The larger, less clearly defined follicles consist of an outer ring

of cells, with small deeply-stained nuclei, and an inner circular mass of cells, with large faintly-stained nuclei.

The adenoid reticulum appears in some places to be in unusually large amount, fibrous, and even muscular, as there are numerous elongated nuclei, which there is little doubt belong to plain muscle fibres (fig. 2, *s.m.*). These cells are sometimes placed end to end in such a manner as to form long fine strands, which wind among the lymph cells. In addition to these strands, definite trabeculae of fibrous tissue, resembling that of the capsule, are present in the lymphoid portion, and may be seen in many cases dividing up the central sinuses into small irregular areas.

Blood-vessels are occasionally met with in the lymphoid tissue, but we have been unable to come to any definite conclusion with regard to the blood supply of the glands.

Varieties of cells.—The cells composing the lymphoid portion of the gland bear a close resemblance to those of adenoid tissue in general.

It will be well, however, to describe the chief varieties met with.

(1) This includes the great majority of the cells. They consist almost entirely of nucleus with a narrow rim of protoplasm. The nuclei vary somewhat in shape, being usually rounded, sometimes oval or triangular, and show nuclear figures.

The amount of protoplasm varies, and there are intermediate forms between this and the following variety. The diameter of nucleus ranges from about $4\ \mu$ to $6\ \mu$.

(2) Cells with a larger amount of protoplasm than No. 1, irregular in shape, greatest dimensions being 8 or $9\ \mu$, nuclei 4 or $5\ \mu$ in diameter. General characters like the first variety.

Varieties Nos. 1 and 2 may contain pigment, either in the nucleus or in the protoplasm. Double and dividing nuclei are frequently to be seen. The nucleus is often of a horseshoe shape.

(3) Cells a little larger than the preceding, with large pale vesicular nuclei, oval or crescentic in shape, with one or more nucleoli.

(4) Large multinuclear cells, containing in some cases seven

or eight nuclei. Protoplasm homogeneous, and staining with eosin.

(5) Large faintly granular cells, stained pale pink with eosin, with no appearance of nucleus. Diameter about $20\ \mu$.

(6) Rather smaller cells than the preceding, with small dark nucleus.

In addition to these are to be seen very clearly the cells of plain muscle fibres, either scattered singly here and there in the section, or forming curved strands in conjunction with the fibrous tissue.

Fixed connective-tissue cells are also to be seen applied to the fibres of the adenoid reticulum.

Most of these varieties were observed by Robertson; but we cannot confirm his statement that, in the multinuclear cells, as the nuclei increase in number, they lose their affinity for logwood, and stain more readily with eosin. It was on these grounds that he assigned a blood-forming function to the glands.

Clarkson came to the same conclusion with regard to their function, in consequence of very different appearances obtained by him in cover-glass preparations.

He found that many of the cells contained circular bodies, about the size of red blood discs, which refused to stain with methylene blue, but stained with fuchsin. These, he suggests, are red cells in process of formation. We have obtained somewhat similar appearances in cover-glass preparations, but are inclined to attach very little importance to them, since we could observe nothing of this nature in sections stained by other methods, although in certain cells in the rat's hæmolymp gland, as described below, appearances of this kind were a conspicuous feature in all our sections. But for these we shall have another explanation to offer (see "Function," below).

We have included above in one common description the glands from the subvertebral region and those found in the neighbourhood of the renal artery, though among the latter are usually found a certain number which contain a much larger proportion of adenoid tissue and less blood-sinus. These constitute Clarkson's second variety, and are constructed as nearly as possible on the plan of a lymphatic gland. Thus we may

divide the whole organ into a cortex and a medulla. The former consists, just as in a lymphatic gland, of large rounded masses between the trabeculæ. But the place of the lymph-sinus is occupied by a blood-sinus in these glands. The medulla likewise consists of elongated, reticulating masses of adenoid tissue and trabeculæ, with blood-sinuses occupying the place of the lymph-sinuses of a lymph gland.

Many of the lymphoid nodules described above are sections of the peripheral (cortical) nodules of these glands, but there are some more deeply or even centrally placed, and some nodules are seen when the section has passed quite through the centre of the gland.

ii. *Equus caballus*.

As already mentioned, we have only examined those glands of the horse which occur in the neighbourhood of the kidney.

They differ only in unimportant details from the glands of the ox and sheep already described.

The amount of lymphoid tissue is greater, however, and shows more tendency to form aggregated nodules than is even the case in the ox.

These nodules are extremely regular in shape, and each one is surrounded by a well-defined sinus, usually of uniform width (see fig. 3). Cells of the varieties 2 and 3 are more numerous than in the previous animals.

iii. *Homo*.

Heneage Gibbs, in dissecting out the renal artery and vein in the human subject, found an oval body measuring a little over $\frac{1}{4}$ in. in length by $\frac{1}{8}$ in. in breadth. It had a fibrous capsule, which varied very much in thickness in different parts of the circumference. This capsule sent in fibrous trabeculæ, dividing the cortical portion into alveoli. In the alveoli were masses of cells resembling lymph corpuscles, varying much in size. Throughout all parts of the structure cell masses were separated from the fibrous trabeculæ by well-defined spaces without reticula, and into these spaces blood-vessels opened directly. The spaces contained red blood corpuscles, so that there was this great difference between these bodies and lymphatic glands:—"In

the one a current of lymph passes through the spaces between the cell masses and trabeculæ, while in the other there is a current of blood."

The author describes, in addition, in these spaces, a number of cells much larger than red blood cells, containing a well-marked nucleus, as large as that of the cells forming the cell masses, but not staining so deeply. In the cell masses the cells are closely aggregated together, and only their nuclei can be made out. The large cells are more numerous in the peripheral than in the central spaces.

These glands undoubtedly correspond to the hæmolymp glands we have described in the sheep and ox, and apparently to Clarkson's second variety.

Robertson describes 'prevertebral hæmolymp glands' obtained from the human subject, in spite of the unfavourable conditions of post-mortem examinations, and in spite of the fact that hæmolymp glands from the human subject usually have their sinuses more or less empty, so that, instead of being bright red, they are pinkish-grey, and approximate to the colour of a lymphatic gland. Histologically, they resemble very closely those of the sheep, the only important difference being that the peripheral blood sinuses are interrupted at places by the lymphoid portion reaching the capsule. In some of the best specimens he obtained, the same forms of cells as he found in the sheep and bullock were clearly made out.

It would seem that some of the bodies must correspond to the 'compound' or 'intermediate' glands we have found in the rat and dog (?).

Since these structures in man are not generally recognised, we have thought it desirable to reproduce the above descriptions in order to call attention to the subject, and we would suggest that it may be worth while for pathologists and others who have better opportunities than ourselves to carefully investigate this question. We have examined some three or four subjects several hours after death, and one almost immediately after, but have not seen any structures bearing a resemblance to the hæmolymp glands of the sheep and the ox.¹

¹ Since the above has been in type I have, by the kindness of Dr Kauffmann, been able to study undoubted hæmolymp glands in a boy aged 9. There were

iv. *Mus rattus*.

In general arrangement, the hæmolymph gland of the rat does not differ essentially from that of the animals previously described; that is to say, it consists of a capsule, peripheral and central blood-sinuses, and a varying amount of adenoid tissue, but in some cases the contents of the sinuses present peculiar and interesting features.

In the earlier specimens we examined (from which fig. 4 is taken), the gland showed large pigment masses of a yellowish-brown colour, consisting mostly of highly refractive globules, having a distinctly oily appearance (fig. 4 (6)). They could not, however, consist of fat, since the specimens had been passed through turpentine and paraffin. These globules are sometimes free, sometimes contained in cells, and are found both in the adenoid tissue and in the blood-sinuses, but when free, chiefly in the former. A large proportion of those contained in cells are, however, in the sinuses. There is also a variable amount of granular pigment (*v.* fig 4, (8)) distributed in a similar manner to the globules.

In many parts of the gland, in the sinuses, are seen fairly large cells (1), having a nucleus deeply stained with hæmatoxylin and very faintly granular, almost homogeneous, eosin-stained protoplasm, the latter being considerable in amount (fig. 4 (2) and fig. 5 η). These cells are mostly circular in outline, and about $11\ \mu$ in diameter, nucleus about $2.5\ \mu$. Some of them are observed to contain two nuclei. Such cells are fairly frequent, and form striking objects in the field.

But of much more interest are certain large cells (2), of varying sizes and shapes, the largest having greatest dimensions of 27 or $28\ \mu$ (fig. 4 (1) and fig. 5, α , β , γ). These are often branched; they crowd many of the sinuses, especially the central ones, and are the most characteristic objects of many of our specimens (fig. 4). Within them are circular bodies, faintly stained with eosin in most cases, in others fairly deeply stained; they vary in size in different cells, but the great majority have about the

at least 50 of the glands in the mesentery and gastro-colic omentum. Although I have not yet examined them very carefully, I can affirm with certainty that they were, some of them at any rate, of the kind described by Robertson.—S. V.

same diameter as red blood discs (*cf.* κ with α , β , γ in fig. 5). The number contained in a cell may amount to twenty or more, or there may be only one. These we consider to be definite globules, and not mere vacuoles; and in fact, in our opinion, they are red blood corpuscles. In many of these cells, in addition to the pale pink globules, there is a certain amount of pigment (*v.* δ and γ , fig. 5), either globular or granular, and in most cases a nucleus (fig. 5, α , β , γ , ϵ). In some instances, however, this last is either absent or obscured by the pigment (θ , fig. 5).

It is curious that in the specimens we have been describing very few red cells were to be found in the sinuses; it would almost appear as if they had nearly all been taken up by the above-described large cells, leaving the sinuses practically free from them. There are, however, here and there, masses of colourless bodies, with a broken circular outline, which are possibly the membranes of red corpuscles, from which the contents have been removed (*v.* λ , fig. 5).

There are intermediate stages between the cells of the first and second varieties described above.

In other glands, however, the appearances were very different. The sinuses were filled with red cells, and few only of the above-described globule-containing cells could be discovered. There was a large amount of pigment, nevertheless, free and contained in cells, both in the adenoid tissue and in the sinuses. This was mostly of a golden-yellow colour. Besides these two varieties of gland are others combining the characters of both. The central sinus contains numerous large cells inclosing globules, while the peripheral sinus is full of red blood corpuscles. It would appear as though the red cells were admitted to the central sinuses only to become engulfed in huge phagocytes, for the purpose of destruction of the corpuscles and the setting free of their pigment.¹

The adenoid tissue of the glands of the rat is fairly uniform in its distribution, and does not form nodules like those of the

¹ In a lymphatic gland from the neighbourhood of the renal artery, in some of the sinuses were found cells closely resembling those of variety 2. It is possible that the function of these cells is to destroy some few of the red corpuscles in the lymph. We have reason to believe that lymphatic glands can exercise this function, since, when the spleen is removed, it is practically certain that its

sheep and ox. Blood-vessels are frequently to be seen in the central adenoid tissue, forming another point of contrast.

In the section dealing with Gross Anatomy, we described certain bodies which had the appearance of being intermediate forms between hæmolymp glands and ordinary lymphatic glands. We guessed from inspection with the naked eye that the peripheral blood sinus was not continuous, but only existent in relation to some portions of the capsule. Microscopically, this is just what we found. They are bodies compounded of hæmolymp and lymphatic glands, or, in other words, they are masses of lymphatic tissue, with occasional peripheral blood sinuses. The details of their structure does not require separate description, as it corresponds with those described above.

v. *Canis familiaris*.

In their minute anatomy, the compound glands of the dog have a greater resemblance to ordinary lymphatic glands than have the corresponding bodies in the rat. Notwithstanding this, the peripheral sinus was in many cases crowded with red blood cells: it contained, however, a much larger proportion of lymph corpuscles than were observed in the sheep and ox.

vi. *Gallus bankiva*.

We have so far been able to find the hæmolymp glands in the fowl and turkey only among birds, and even here they are not invariably present.

The greater part of the gland appears to consist of sinus, and there is very free communication by means of wide channels between the peripheral and central sinuses. These are packed with nucleated red blood corpuscles and occasional large masses of yellowish-brown pigment, apparently not inclosed in cells, but free in the sinus. There are also numerous small pigment patches. Many red cells are to be seen in the adenoid tissue.

function is taken on by the lymphatic glands. It is only reasonable to suppose that this function is carried on normally to a small extent. One of us (Vincent, *Trans. Zool. Soc.*, vol. xiv. part iii. No. 1, in the press, and *Birm. Proc. Nat. Hist. and Phil. Soc.*, 1896, vol. x. part i.) has suggested that a similar function is performed by the so-called head-kidney of Teleosts.

Fairly strong trabeculae run in from the capsule. Blood-vessels are frequent, both in the adenoid tissue and in the sinuses. In the latter situation the arteries appear to be supported by the reticulum. The distinction between adenoid tissue and blood sinus, although as definite as in other hæmolymp glands, is not so striking on casual observation, on account of the red cells being nucleated, and thus not offering such a marked contrast to the lymph cells as do the non-nucleated red cells of a mammal.

In the sinuses are a number of rather large cells, 10 to 12 μ in diameter, nucleus 6 to 8 μ , and in the adenoid tissue are numerous cells with large, oval, vesicular, faintly-stained nuclei, like those described in the sheep.

The lining epithelium of the sinuses has not been made out with certainty, but we think it probable that it exists.

We have also noted in the fowl similar appearances, though to a slighter extent to those in the rat, *i.e.*, large cells containing structures which we interpret as red cells in process of destruction.

In *Anser cinereus* a small accessory spleen was found in the gastro-splenic omentum. The spaces between the cells of the splenic pulp were wider than usual, and approximated towards the condition of sinuses, so that the appearance of the structure was almost midway between ordinary spleen and hæmolymp gland. The adenoid tissue was gathered together as usual in the spleen into Malpighian bodies, but these were larger and more diffuse than usual. In *Meleagris gallopavo* the glands were precisely like those of the fowl.

vii. *Pisces*.

In *Cyclopterus lumpus*, in front of the lymphatic head-kidney, is a dark blood-red rounded body on each side. This structure has been previously considered by one of us¹ to represent simply a constricted off portion of the head-kidney, and described as such. On looking over the slides again, however, it has struck us that the structure of this body is practically identical with that of the hæmolymp glands we have been describing. There is, surrounding a large part of the organ, a well-defined

¹ Vincent, *Trans. Zool. Soc.* (in the press).

peripheral blood sinus, and there are many central sinuses separated from one another by irregular masses of adenoid tissue, just as in the hæmolymp glands of the sheep and ox. The sinuses are so full of red corpuscles, and the outlines of these are so distinct, that it is difficult to verify with certainty the existence of a reticulum, but it seems very likely that this is present. A delicate endothelium can be seen in many places lining the sinuses.

This body is sufficiently like the hæmolymp glands of mammals to warrant the description here.

Again, on examining sections of other 'head-kidneys,' it is seen that in many parts of them there are blood sinuses quite analogous to those above described, but very irregularly distributed.

Still other 'head-kidneys,' *e.g.*, that of *Molva vulgaris*, have a structure almost identical with that of spleen, except that there are no Malpighian bodies.

These facts are interesting, inasmuch as they point to a transition between lymphatic, splenic, and hæmolympathic structures. This point will be referred to again below.

6. FUNCTION.

These glands are certainly of considerable importance in the ox, sheep, horse, rat, and probably also in man. But although they are undoubtedly found in birds, they are so few in number, small in bulk, and inconstant in occurrence, that we cannot reasonably attribute to them any important function.

We can offer no theory as to the reason of their restricted occurrence in mammals.

We have seen that the glands consist mainly of two distinct parts, adenoid tissue and blood sinuses. The former has every appearance of functioning, as does the adenoid tissue of an ordinary lymphatic gland, *i.e.*, in the manufacture of leucocytes; for the majority of the nuclei have nuclear figures, and many are seen to be dividing. But the replacement of the lymph sinuses by others containing blood suggests at once some function with reference to the red corpuscles.

This function has been considered by previous observers to

be the production of red blood discs. Robertson states that the nuclei of the multinuclear cells, as they increase in number, lose their affinity for logwood, and stain more readily with eosin, at the same time approximating in form and size to red blood cells. Hence he concludes that these multinuclear cells manufacture the red blood corpuscles. We have already stated that we find it impossible to verify his observations.

Clarkson bases the same view upon different appearances, viz., in cover-glass preparations, circular pale bodies in certain cells. These he considers to be red cells in process of formation. These we could not find with certainty in the ox or sheep, but found them very strikingly present in the rat (*vide supra*). We differ, however, from Clarkson in our interpretation of them. That they are red corpuscles we can have little doubt, but whether in process of formation or about to be destroyed is a question which presents more difficulties.

We attach considerable importance to the masses of pigment found in different situations in these glands. It appears to us highly probable that it is in some way or other derived from the hæmoglobin of the red discs; and this in itself is strongly suggestive of the destruction of the corpuscles. Moreover, the pigment is frequently contained in nucleated cells, and appears to be the result of some activity on their part. In the ox, sheep, and horse, we have not succeeded, so far, in finding any further evidence of any great activity in regard to the red discs, though the lymph corpuscles in the adenoid tissue are seen to be multiplying by karyokinesis. But in the rat the difficulty is not in obtaining evidence of activity, but in deciding what the nature of this activity is.

We have little hesitation in stating that the large cells of variety 2 found in the sinuses (see above) are amoeboid leucocytes of unusual dimensions,—are, in fact, phagocytes; and we have but little less hesitation in pronouncing the pale globules within them to be red cells.

Now, nothing is known of intracellular formation of blood discs in the adult, while we are familiar with the fact that they are taken up and destroyed by large cells in the spleen. Again, when red cells are produced in the adult they are nucleated, but here the bodies under discussion are always non-nucleated. It

would therefore, on the whole, appear much more likely that the red cells are taken up by these phagocytes in order to be destroyed, and that the pigment is the result of the breaking down of the hæmoglobin. Moreover, we believe that we have observed some of the stages of this process.

Robertson's view we shall not further discuss, because we have been unable to verify the actual appearances he observed.

What we imagine to take place in these glands is somewhat as follows :—

Certain large, branched cells, which we take to be amœboid, surround and take into their substance, after the manner of phagocytes, a number of red blood corpuscles (1–20). Then gradually the colour and shape of the red discs change, till we get pigment globules of varying tints. Sometimes these become aggregated together to form large pigmented cells, and often the nucleus is obscured. At other times the pigment becomes broken up into fine granules, which become darker and darker till they are almost black. Sometimes, too, the pigment becomes set free from the cells, and is distributed in masses and granules in different parts of the gland.

These are practically the same appearances as have been described by Kölliker and others as occurring in the process of corpuscle destruction in the spleen.

7. SUMMARY.

1. The hæmolympth glands, so far as is known at present, exist in man, and in *Ovis aries*, *Bos taurus*, *Equus caballus*, *Sus domesticus*, *Mus rattus*, and *Canis familiaris* among mammals; in *Gallus bankiva* and *Meleagris gallopavo* among birds. A strictly comparable structure (histologically) exists also in the 'head-kidneys' of certain Teleostean fishes. In some of the above-named animals the glands do not appear constantly.

2. They have been searched for but not found in *Rana temporaria*, *Bufo vulgaris*, *Tropidonotus natrix*,* *Crocodylus*,* *Phœnicopterus*,* *Anser cinereus*, *Psittacus erithacus*, *Columbia livia*, *Camelus dromedarius*,* *Mus musculus*, *Cavia cobaya*, *Lepus cuniculus*, *Mustela furo*, *Felis Pardus*,* *F. domestica*, *Talpa*

* The species marked with an asterisk have not been examined by ourselves.

europæa, *Erinaceus europæus*, Catarrhine monkey (species not noted).

3. In our opinion, they are modified lymphatic glands, and probably developed from them, consisting, as they do, of adenoid tissue, with blood-containing sinuses.

4. *In certain animals, e.g., rat and dog, there are glands which differ little to the naked eye from lymphatic glands, but which are found on microscopic examination to contain blood sinuses.*

These, however, can usually be distinguished macroscopically from ordinary lymphatic glands by their exhibiting blood-red patches of varying dimensions on their surface.

5. We consider it doubtful whether the hæmolymp glands have anything to do with the production of red blood corpuscles, but *they present every appearance, in some cases at least, of taking part in the destruction of these elements.*

6. We believe that we have found gradual transitions from hæmolymp glands, on the one hand, to ordinary lymphatic glands, and, on the other hand, to the structure of spleen. So that no hard and fast line can be drawn marking off these structures from one another. A lymphatic gland has only to contain blood in part or the whole of its sinuses to constitute itself one of the varieties of hæmolymp glands. In certain accessory spleens, moreover, the splenic reticulum is so widened out as to approximate to a blood sinus of a hæmolymp gland, and the Malpighian bodies are so diffuse as to resemble the lymphoid portions of the blood lymph glands. So that spleen, hæmolymp glands, and ordinary lymphatic glands form almost a continuous series.

[EXPLANATION

EXPLANATION OF PLATE VIII.

References common to Figs. 1, 2, 3, 4.

- bld.v.*, blood-vessel.
bld.s., blood sinus.
c., capsule.
c.bld.s., central blood sinus.
p.bld.s., peripheral blood sinus.
f., fat outside capsule.
l., lymphoid tissue.
r., reticulum of sinus.
r.c., red blood corpuscles.
s.m., nuclei of plain muscle.
wh.c., leucocytes in blood sinus.
 1, large cells containing globules.
 2, cells with homogeneous eosin-stained protoplasm.
 3, branched nucleated cells of reticulum.
 4, débris of blood in sinus.
 5, epithelium of blood sinus.
 6, pigment mass in lymphoid tissue.
 7, large cell in sinus containing pigment.
 8, pigment dots.

Fig. 1. Section of hæmolymp gland of sheep, showing general relations of capsule, adenoid tissue, and blood sinus ($\times 40$, drawn with Zeiss' camera lucida).

Fig. 2. Portion of hæmolymp gland of sheep, more highly magnified, showing details of structure of capsule, sinus, adenoid tissue, endothelium, etc. (Leitz. Pantachrom. 3 mm.).

Fig. 3. Portion of hæmolymp gland from renal artery of horse, showing nodule of adenoid tissue surrounded by a blood sinus. The endothelium is well shown.

Fig. 4. Small portion of hæmolymp gland of rat, showing adenoid tissue and blood sinus, with contents, pigment, &c.

Fig. 5. Cells from sinus of hæmolymp gland of rat (Zeiss' water immers. Compens. Oc. 12).

- $\alpha,$
 $\beta,$ } Large cells containing pale globules (Var. ii., see text).
 $\gamma,$
 $\delta,$ Pigmented cell containing one globule.
 $\epsilon,$ Slightly differs from α, β, γ ; shows clear space round nucleus.
 $\zeta,$ Nucleated cell with pigment, but no globules.
 $\eta,$ Cell with homogeneous eosin-stained protoplasm (Var. i., see text).
 $\theta,$ Cell containing pigment partly in form of globules.
 $\iota,$ See η .
 $\kappa,$ Red blood corpuscle.
 $\lambda,$ Membranes of red blood corpuscles.
 $\mu,$
 $\pi,$ } Leucocytes of the most common variety.

THE ACTION OF THE PRODUCTS OF THE ORGANISM
OF DIPHTHERIA ON THE HEART MUSCLE OF THE
FROG (*Rana temporaria*).¹ A PRELIMINARY NOTE. By
GORDON SHARP, M.D. Edin.

IN the following research an endeavour is made to ascertain if the products of the Klebs-Loeffler bacillus have any action directly on the heart muscle. Cases of diphtheria often die suddenly; and although this may be due in many instances to paralysis of the vital centres, there may be cases where the poisonous products circulating in the blood have a debilitating action on the heart muscle itself, just in the same way as vegetable alkaloids and glucosides. This "imperfect or altered condition of its circulating blood" on the tissues was long ago observed by Sir Thomas Watson in his oft-quoted lectures on diphtheria, but this phase of the question would not appear to have received the attention it deserves.

In the following experiments the methods employed are fully explained.

Experiment I.—At a temperature of 65° F. a healthy female frog, well nourished, was pithed, and a cannula inserted in the ventricle, the septum being divided and the pericardial vein tied. The cannula was tied in, the heart removed from the body, inserted in saline solution, and attached to a perfusion apparatus. Normal saline solution was then passed through the heart, and kept up at a nearly constant pressure for half an hour, during which time the heart-beats were regular and strong in character. At the end of half an hour normal saline solution containing dissolved in it the products of a culture tube from a case of true diphtheria of the throat was then turned on, the pressure being kept constant.

Result :—

1. For the first fifteen minutes the heart beat stronger.
2. For the second fifteen minutes diastole becomes prolonged.
3. The next fifteen minutes are marked by cycles of one regular systolic beat and one regular diastolic beat and one *long* diastole.

¹ Part of a thesis for the degree of Doctor of Medicine, University of Edinburgh.

4. The fourth fifteen minutes show systole less complete and diastole as *prolonged* as in the last cycle.

5. The heart is now evidently getting weaker, and the poison is stopped, and normal saline solution again turned on and is passed through for three-quarters of an hour, but the heart stops in diastole. Despite this, saline solution is still passed through. In half an hour later the organ recovers somewhat and weak systolic efforts are made, but there is never a strong beat, and the heart stops in full diastole.

I should add, that in the various changes from *pure* normal saline to *poisoned* normal saline solution, the heart was respectively suspended in the same fluid as was passed through its chamber.

Experiment II.—Under the same conditions as in Experiment I., a well nourished, healthy female frog was employed. To normal saline solution feeble systolic and diastolic movements were observed. Saline solution was continued for fifteen minutes, after which the heart was allowed to rest, the tube being clamped. After a short period, saline was again turned on. The heart-beats were as before, being regular but not strong, this being evidently the normal character of the heart.

The poisonous saline was now turned on and the effect watched.

Result :—

1. For fifteen minutes the beats were much as under normal saline.

2. At the end of fifteen minutes diastole became markedly prolonged.

3. The heart was evidently failing, and the *poison* tube was clamped and *pure* saline turned on.

4. At the end of a few minutes diastole became less prolonged, and slowly the organ returned to the weak regular systole and diastole as when saline was first turned on.

5. The *poisoned* saline was once more turned on, and revealed a condition similar to that already described. At this time the poison was continued for fifteen minutes.

6. *Pure* saline once more passed through, and again the heart recovered, but took longer time than before. Continued for fifteen minutes.

7. Poison now passed through. Effect as before; diastole being prolonged. The heart is getting weaker, and finally stops in diastole.

8. *Pure* saline is again run through and kept up for half an hour, but the heart fails to respond.

From these experiments it would appear as if the products of the organism of *diphtheria* acted directly on the heart muscle.

Deductions and Practical Applications.—Diphtheria poison is to be classed with the acids which have as their *final* action the stoppage of the heart muscle in diastole. In the same list we find muscarine, emetine, apomorphine, the alkaloids of green hellebore (*Veratrum viride*), potassium salts, and certain double salts, notably those of copper and zinc. But to some of these last mentioned we find the relationship is even closer than at first appears. The potassium salts and double salts just named first excite and then *finally* paralyse the heart muscle, and it seems as if this was the action of diphtheria poison. In Experiment I. the heart beat stronger for the first fifteen minutes of the passage of the poison through its chamber; in Experiment II., if for the first fifteen minutes the beats were not stronger, they were at least no weaker than with normal saline solution.

Pharmacology is useful in that it confirms, supplements, or interprets our clinical evidence. It further points to the rational treatment. By combining the clinical and the pharmacological evidence we frame our therapeutics. In the present instance we have an indication to avoid all remedies which have for their final effect depression of the heart. Hence alcohol, which is often given in large doses in diphtheria, should be especially watched in its action. Our aim and object should be to obtain the benefits of stimulation, and none or as little as possible of its evils. This happily we can do now by giving, either alone or with the alcohol, the various digested foods, which not only stimulate the tissues, but also supply them with the necessary materials for their rapid growth and repair. It was long ago observed by clinicians that diphtheria was especially fatal in its effects on those of a "relaxed habit of body." Here, again, the clinician and the pharmacologist join issue; and I believe their evidence further supports the general line of treatment which I have just advocated, namely, stimulation without ultimate depression. This is especially important in the treatment of the young child.

AN INVESTIGATION INTO SOME OF THE PRINCIPLES OF AUSCULTATION. By ALBERT A. GRAY, M.D. Glasgow.

THE object of this paper is to consider the conditions which affect the transmission of sound through the lungs. The first part is concerned with the *intensity* with which sound is conducted through those organs, both in health and disease, while the second part relates to the changes in *quality* which it may undergo in transmission. Existing theories, especially those of Skoda and Laennec, will be discussed throughout the paper.

The experiments described were carried out in the physiological laboratory of Glasgow University, and the writer wishes to thank Professor M'Kendrick and Dr Fraser Harris for their help.

Besides those just referred to, another series of experiments was carried out in the Western and Victoria Infirmaries, and thanks are due to Dr Gemmell and Dr Napier for permission to perform these in their wards. This series is not described in detail, but only the method of performing the experiments, and the general results obtained.

PART I.

Clinical Experiments.—The method of performing these experiments was as follows:—

A tuning-fork (A1.440 vibs.) was set vibrating, and placed on various points on the surface of the patient's chest. The points usually selected were, the cricoid cartilage, the manubrium sterni, and the lower part of the sternum, just above the ensiform cartilage. While the fork was held in position by an assistant, the experimenter listened for the sound over the back of the chest with a stethoscope. Of the patients examined in this way, four were suffering from pleurisy with effusion, one from tumour of the lung accompanied by pleuritic effusion, and five from phthisis pulmonalis.

The results obtained from these experiments were interesting.

Thus, when the stem of the fork was placed upon the cricoid cartilage, the difference in intensity of the sound heard over the

two sides of the chest behind, corresponded exactly with the difference in intensity of the sound of the patient's voice heard over the same areas. That is to say, in cases of phthisis, both the sound of the tuning-fork and the voice were heard better over the diseased region than over the corresponding healthy one of the opposite side; while in the cases of pleurisy, these sounds were heard more feebly over the diseased than over the healthy parts. When, however, the instrument was placed upon the lower part of the sternum, the sound was heard behind, better over the diseased surface than over the healthy parts: this was true both in the cases of phthisis and pleurisy. This fact is the most important result of the experiments, because it is not in accordance with the teaching at present in vogue concerning the diminution in intensity of the vocal resonance in pleurisy, viz., that a layer of fluid in the pleura acts as a great hindrance to the transmission of the voice through the chest. If this hypothesis were true, then we would expect the sound of the tuning-fork, when placed upon the sternum, to be heard much less faintly through the fluid than on the healthy side, the conduction by the thoracic walls being equal on both sides. As a matter of fact, the layer of fluid is not such a serious obstacle to the transmission of sound as it is stated to be in works on physical diagnosis. The real cause of diminution of vocal resonance and fremitus is to be found in the collapsed and relaxed state of the lung itself which occurs in pleurisy with effusion. In other words, the sound of the voice reaches the fluid with greatly diminished intensity compared with that with which it reaches the chest wall on the healthy side. This matter, however, will be discussed more fully at a later stage.

The above remarks form the summary of the results of the experiments on living patients. The clinical histories of the individual cases are not related, as they are in the original article.¹

PART II.—A.

Differences in Intensity of Sound conducted through the Lung.

A healthy adult was selected, and a tuning-fork (A1.440 vibs.) struck, and placed on the suprasternal notch. On listening over

¹ Thesis, for the degree of M.D. of Glasgow University.

the back with the stethoscope, the sound was heard best over the first dorsal vertebra, and decreased in intensity on proceeding down the middle of the back; at the lateral parts of the back it was heard less intensely than over the vertebræ, and over these parts also the sound decreased in strength on proceeding downwards.

When the instrument was set in vibration and placed upon the middle line of the sternum, just above the ensiform cartilage, it was heard very well over the back on placing the stethoscope over the 7th, 8th, and 9th dorsal vertebræ. The sound was also very well perceived over the regions on each side of these bones, and for some reason it was rather better heard two or three inches to the left of the middle line than at corresponding points on the right back. [The writer has since found that this is due to the position of the heart, especially the ventricles lying to the left of the middle line.]

Keeping the tuning-fork in the same position, but moving the stethoscope upwards, the sound did not lose in intensity the whole way up the spine; if anything, it rather increased. The slight difference in intensity noted lower down between the two sides, disappeared on proceeding upwards.

During these experiments, the intensity of the sound was heard to increase as inspiration proceeded, and to decrease with expiration.

On placing the instrument upon the crico-thyroid membrane, with a small piece of wood interposed in order to make sufficient volume of sound, the note was, of course, not heard with anything like the same intensity as in the former experiments. But, strange to say, the difference in intensity during inspiration and expiration was more marked than before; and this difference became still more pronounced if inspiration and expiration were attempted with a closed glottis. This latter phenomenon may perhaps be explained by the fact that the respiratory murmur did not mask the sound of the fork.

On inquiring into the cause of this difference of the conduction of the sound during the two portions of the respiratory act, care must be exercised. At first, the writer was inclined to attribute it to the difference in tension of the structures forming the thoracic walls. But although this may partly explain the fact, it does not entirely do so, because—

(1) The nearer the fork was brought to the suprasternal notch, it was noticed that the difference in intensity of the sound during inspiration and expiration became more pronounced.

(2) The difference was not more marked at those parts of the thorax where the greatest changes in the tension of the parietes occur during respiration, viz., the lower parts of the thorax. On the contrary, it was noticed equally well all over the chest.

(3) The difference was most pronounced when the stem of the fork was placed upon the trachea or larynx, and it is precisely in this position that most sound would travel through the trachea, bronchi, and lung to the stethoscope, and least by the parietes.

Considering, therefore, that this difference might be due to changes in tension of the intrathoracic structures, the writer performed the following experiment:—

After repeated attempts to procure uninjured lung from the butchers' shops, as these were always lacerated, a dog was killed, and the lung and trachea carefully removed from the thorax.

A cork with a metal tube running through its long axis was inserted into the open end of the windpipe, and firmly tied there. An india-rubber tube was fastened over the projecting end of the metal tube, and placed in connection with an air-pump.

A tuning-fork (A1.440 vibs.) was kept vibrating at a constant intensity by means of an electric battery and coil, and the stem of the instrument was placed upon the cork. An assistant inflated the lungs by means of the air-pump or the mouth, as the experimenter listened over the organs. As distension proceeded, the sound grew in intensity until full inflation was reached. On letting the air gradually escape, the sound died away as collapse ensued. The experiment was repeated several times.

It should be noted that during this experiment the sound reaches the lungs by the trachea only, and not by the dish or table on which the organs are resting; hence the windpipe should be raised up from the table or dish, and the wrist of the assistant must not be allowed to rest upon the table.

It is important that the organs should not be suspended by the trachea, because their weight alone causes tension; they may be suspended in a towel. The end of the stethoscope must not be pressed into the collapsed lung, as is so liable to occur,

but must be applied gently and equably throughout the experiment. At the bedside we are never able to compress the lung with our stethoscope.

From these experiments on living, healthy and diseased subjects, and from those upon the lungs extracted from the thorax, it would appear that the elasticity of the respiratory organs and the tension which they may assume has a considerable effect upon their power of transmitting sound. We would, indeed, expect this; and the simplest acoustical experiments show that tension of elastic substances plays a considerable part in the conduction of sound through them. The following is an example:—

One end of a piece of string is tied to the stem of a tuning-fork, and the other to the stem of a stethoscope. Let the earpiece of the stethoscope be applied to the ear while the tuning-fork is vibrating, and put the string into alternating states of tension and relaxation by pulling the fork away from the stethoscope and then bringing it nearer; the difference in the intensity of the sound will be very apparent during relaxation and tension.

It was with surprise, therefore, that on looking through various works on Physical Diagnosis, the writer was unable to find any reference to the effect of tension of the structures upon the sound-conducting power of the respiratory organs. Under the subject of auscultatory changes in the voice, which is the place where it should be considered, there was found no word upon the subject.

As this paper, besides being an investigation into the phenomena of sound-conduction through the lungs, is also a criticism on the existing hypotheses in regard to the same phenomena, it would be advisable here to give a synopsis of the two chief theories of vocal resonance.

(1) Laennec held that the voice was transmitted through the lung by the walls of the trachea, bronchi and bronchioles, and alveoli; and further, that in pneumonia and other conditions in which the organs became denser, the voice was transmitted better because the mass became more homogeneous; that is to say, in health the “*tissu rare et mêlé d’air du poumon*” was a bad conductor (*Traité de l’auscultation médiate*, 4th edition, tome i. p. 83),

while in condensation and collapse "le tissu du poumon, rendu plus dense, en devient meilleur conducteur du son" (*ibid.*, page 73).

(2) Skoda maintained that the voice was transmitted down to the lung by the air in the trachea and bronchi, and was resonated ('consonanz' was the word he used) within these structures. In condensations of the lung this resonance was increased, because the bronchi were surrounded by dense tissue instead of the normal spongy lung. (*Treatise on Auscultation and Percussion*, 4th edition, translated by Markham, 1853, page 39.)

Of these two hypotheses, the first is nowadays the most generally received; but Skoda has many followers. Many physicians find difficulty in admitting either to be wholly correct (*vide* Walshe, *Practical Treatise on Diseases of the Lungs*, 3rd edition, 1860, pp. 142-164: "there may be some property or properties of the substances within the chest which, in a manner unknown to us, has great effect upon the conduction of sound through those substances." *Vide* also Pye-Smith and Fagge, *Principles and Practice of Medicine*, 3rd edition, 1891, vol. i. p. 940: concerning vocal resonance, "the complete physical explanation has not yet been given").

Into the literature of this subject it is not necessary to enter, however interesting. A complete historical description of the various theories and discussions upon the subject will be found in Niemeyer's *Handbuch des theoretischen und klinischen Percussion und Auscultation vom historischen und critischen Standpunkte*, 1871, zweite Band zweite Abtheilung, pp. 1-82. In addition to this, other works of reference are given at the end of this paper.

There is no doubt that Laennec's hypothesis, as it is accepted nowadays, will be found to explain or coincide with many of the phenomena of vocal resonance and fremitus and the respiratory murmur, found in disease, *e.g.*, in pneumonia: as we find increase in density and homogeneousness of the lung, so also we find *usually* increased vocal resonance and fremitus. In phthisis the same holds true. Increased density and homogeneousness seem to explain the facts exceedingly well.

But there is a class of cases which gives ambiguous and often contradictory auscultatory signs, which do not fit in with this

theory, and indeed rather do tend to prove its insufficiency. The signs referred to are those which are met with in cases of *pleurisy with effusion*: these vary considerably, and it would perhaps be better at first to take into consideration those which are present in a typical case; exceptions may be discussed later.

In a typical case, then, the following are the usual signs:—

(1) *Ægophony*.—This is found, as Laennec states (*Traité de l'auscultation*, 1837, tome i. page 93), at the upper margin of the effusion, where the layer of fluid between the lung and parietes is becoming thin.

(2) Over the remaining portion of the chest which covers the effusion, vocal resonance and fremitus are greatly diminished, (3) and over this area the respiratory murmur is greatly diminished.

Taking these signs as a whole, it will be seen that they are the opposite of those which obtain in pneumonia.

Having briefly considered the auscultatory signs, let us now look at the pathological conditions of such a case. Fluid is poured out into the cavity, and the lung tissue below the level of the fluid falls in. This falling in of the lung is called in many text-books 'compression.' Such a term is, in part at least, wrong. There is no compression unless the fluid be large in amount. The lung in a healthy chest is a highly elastic structure, kept constantly in a state of considerable tension by atmospheric pressure; and if gases or fluids are poured out into the pleural sac, a spontaneous falling in takes place, and if sufficient effusion is present, the tissue is reduced to a flabby mass. Should still more fluid be poured out, then true compression or *carnification* sets in, as evidenced by the fact that the blood is pressed out of the tissue.

It is further to be remembered that the normal organs, as found at the post-mortem table of the hospital, are not in a state of *complete* relaxation, because plugs collect in the bronchi and bronchioles, and prevent the elastic tissue from fully expelling the air in the alveoli.

Even if the thorax be opened immediately after death, the elasticity of the organs is not quite satisfied, because in life the "contractile force of the involuntary fibres of the bronchi come into play; hence the force for expelling air is greater than after

death" (M'Kendrick, *Text-book of Physiology*, 1889, vol. ii. p. 305).

Lichtheim has proved that the elasticity of the lung does not become exhausted until the alveoli are completely emptied of all their gaseous contents. (Fagge and Pye-Smith's *Principles and Practice of Medicine*, 1891, pp. 959 and 1021.)

During this process of collapse, it is self-evident that as the elasticity of the lung is being exhausted, the density of the organ is being increased. From this, if Laennec's hypothesis were true, we would expect the intensity of the vocal resonance to be increased in pleurisy. As a matter of fact, the opposite is the case: the voice is conducted very much worse than in health, except at the upper margin of the fluid, where it is generally rather increased in intensity.

In order to explain this anomaly, physicians have brought in another factor, viz., the interposition of a layer of fluid between the lung and the chest wall. In other words, if we could place the stethoscope upon the collapsed lung itself, we would find a considerable increase in the vocal resonance, because the lung is more dense and homogeneous. The layer of fluid, however, stops the transmission of the sound. There are two ways of accounting for this loss, to be found in text-books:—

(1) That the sound is stopped in the fluid itself.

(2) That the loss occurs not in the fluid itself, but at the points of transmission from the solid lung to the fluid, and again from the fluid to the thoracic parietes.

Of these, of course, the first is acoustically absurd; pleuritic fluid being, like other liquids, among the best conductors of sound which exist. This explanation, therefore, may be cast aside altogether.

The second explanation is based upon more accurate acoustical truth; but even in this case it is not very difficult to show its weak points. The following considerations will show the insufficiency of the theory:—

(1) Towards the upper margin of the fluid, where the layer of it is only about half an inch thick, the vocal resonance, in the form of ægophony, is usually considerably more intense than the normal, while lower down it is very much less so. Yet there is just as much loss of sound by transmission from solid to

liquid, and *vice versa*, as lower down. This is a very serious objection to the hypothesis.

(2) On referring to the clinical experiments with the tuning-fork upon patients suffering from pleurisy with effusion (page 203), it will be seen that if the fork were placed upon the larynx the sound was transmitted with less intensity through the diseased side, just as the voice is; but if the instrument were placed upon the sternum, just above the ensiform cartilage, the sound was heard best over the diseased side. In this latter case, then, the sound was not diminished by the intervention of a layer of fluid, so much as by the healthy lung on the other side (the bone transmission on both sides being, of course, equal).

(3) It is found that in cases of tumour of the lung the vocal resonance is generally feebler on the diseased side than upon the healthy one, even when there is no fluid in the chest: the explanation completely falls to the ground in this case.

The truth of the matter is, that this explanation of loss of vocal resonance in pleurisy was never needed: it was only brought in to buttress up a theory which is wrong, viz., that collapsed lung was a better conductor of sound than the healthy organ.

The falseness of this theory was proved long since by Skoda. The writer has also satisfied himself definitely upon this point by experiment (page 204). Now, there being no doubt about the fact that collapsed lungs are worse conductors than those in the distended condition, the real truth of the cause of diminution of vocal resonance is plain enough, viz., the sound is lost in the lung itself, and not by transmission through a layer of fluid.

The writer does not mean to insinuate that there is absolutely no loss in this transmission; on the contrary, there certainly is, just as there is loss in transmission from any substance, solid, liquid, or gaseous, to another substance. What he wishes to lay stress upon is, that this loss by transmission is not sufficient to account for the great diminution of vocal resonance and fremitus in the particular case of pleurisy with effusion, especially as, *according to the present theory*, the sound reaches the visceral pleura with considerably greater intensity than normally.

The writer's explanation of the auscultatory vocal phenomena

found in typical cases of pleurisy with effusion is as follows:— The collapsed portion of the lung is a worse conductor of sound than the healthy part because its tension is relaxed, and this accounts for the diminution of vocal resonance and fremitus over the greater part of the area which is dull to percussion. But at the upper margin of the effusion there may be several rows of infundibula which have not yet undergone collapse and are still tense, hence the sound is not diminished over that area: the reason why it is so often increased in the form of ægophony is, that certain elements of the voice undergo true resonance; but this will be discussed at a later page.

Concerning the very poor sound-conducting power of collapsed lung, the following experiments are of practical value:—

A collapsed sheep's lung was obtained from the butcher, and a small block of wood tied into the trachea. A mass of the lung parenchyma distant from the trachea was tied tightly round with string, the two ends of the string being again tied round the stem of a stethoscope.

A tuning-fork was struck, and held on the block of wood by an assistant. If the stethoscope were applied to the ear in such a way that there was little or no tension upon the lung structures, the sound was heard very feebly; but if the tension upon these organs were increased by dragging them away from the stethoscope, at once the intensity of the sound became very much increased.

This experiment may be modified in various ways; *e.g.*, instead of using string to connect the stethoscope and lung, the instrument may be applied directly to the tissue, and the tension of the latter be increased and diminished alternately by dragging on it by the hand; the sound is observed to vary in intensity directly with the tension.

Similarly, if, instead of placing the tuning-fork upon the trachea, it be applied to any part of the organ while the stethoscope is placed at some distance, exactly the same phenomena are noticed: with increased tension there is always greatly increased sound-conducting power.

These experiments teach us one fact of the utmost importance, which is this:—

The sound-conducting powers of the lungs may vary enormously

with changes in the tension, and without any changes in density or resonating or reinforcing power.

Summing up the matter on the foregoing pages in relation to pleurisy with effusion, it would seem that we are justified in making the following statements:—

(1) The loss or diminution of vocal resonance and vocal fremitus over the site of a pleuritic effusion is due to the collapse of the lung which ensues, and not, or only in the slightest degree, to the intervention of a layer of fluid.

(2) The presence of undiminished vocal resonance at the upper margin of the fluid may be accounted for by supposing that a small area of distended lung tissue is present at this part. The fact of the increased vocal phenomena here will be explained under the heading *Ægophony*.

(3) If adhesions be present in a case of pleurisy with effusion, and if these adhesions render the collapsed tissue tense, there will be no diminution of the auscultatory vocal signs, and these may even be increased in intensity. This statement coincides with a practical point, viz., that many skilful physicians, when about to puncture the chest in cases of pleurisy, will avoid entering the trochar at a point where the vocal signs are undiminished or increased, because they know that probably enough solid tissue will be encountered, and not the fluid. Unfortunately, however, adhesions do not always cause increased tension.

An instructive method of showing how adhesions may render the lung structures tense, is to take a lung to which adhesions are attached, from the thorax in the post-mortem room, and make a cut through the adhesion and into the lung parallel with bronchioles and bronchi. On dragging the adhesion gently outwards, the bronchioles and smaller bronchi will at once stand out as tense bands.

(4) To generalise from the case of pleurisy: if other substances than fluids occur in the pleural cavity or the lung parenchyma, similar vocal signs are present; *e.g.*, solid growths, by occupying space in the thorax, allow the tissues to collapse, either directly by their bulk, or indirectly by obstructing a bronchus.

In these cases, also, vocal resonance and fremitus will be diminished unless the growth, besides producing collapse, also causes tension of the structures: under such conditions, the auscultatory signs of the voice may be undiminished, or even increased.

Needless to say, the remarks above apply to empyema and pneumothorax as well as pleurisy.

Having considered the subject of sound-conduction through the lung in the case of pleurisy and analogous conditions, let us go forward and consider the same subject in relation to pneumonia.

Pneumonia.

Pursuing a different course from that taken up in the consideration of pleurisy, the physical pathological conditions will first be briefly epitomised.

In the first stage—Engorgement.—"The lung is of a dark red colour, the capillaries being highly injected. To the touch it is inelastic, and on pressure leaves a pit behind. Though heavier than normal, the diseased portion still floats in water and contains a little air."

Second stage—Red hepatisation.—"The lung parenchyma is little altered It (the lung) is now much firmer and heavier, does not crepitate, and sinks in water. Even on external examination the affected part looks bulky."

Third stage—Grey hepatisation.—"The affected part becomes grey. It retains the firm character and granular appearance of the previous stage."

Last stage—Resolution.—"The lung is still solid, and sinks in water, but its firmness is gone." (Quoted from Coats, *Manual of Pathology*, 1883, pp. 531-535.)

The auscultatory signs of pneumonia are as follows:—

1st stage—Engorgement.—"Pneumonic crepitation is present."

2nd stage—Hepatisation.—"Dulness on percussion, bronchial breathing, and bronchophony, with increased tactile vibration, are developed."

3rd stage—Resolution.—"The peculiar auscultatory signs disappear, and are commonly replaced by râles. The percussion note may remain long deficient." (Pye-Smith and Fagge's *Principles and Practice of Medicine*, 1891, vol. i. p. 989.)

It will be observed that the stages of red and grey hepatisation are put under one heading in the clinical description.

Comparing the pathological and clinical descriptions given above, it is difficult to see in what way the accepted theory of increased density *completely* explains the auscultatory changes.

In the first stage, for instance, there is undoubtedly increase in density of the lung tissue, yet the vocal resonance remains unchanged. But let this point be waived, as cases seldom come under accurate observation so early.

In the second stage, in *typical* cases, the vocal signs are explicable by the commonly accepted hypothesis. But, as will be shown later, there are undoubted cases of pneumonia, where the auscultatory changes in the voice are incompatible with that theory.

It is in the last stage—resolution—where this theory falls to the ground; because it is found at this stage the increased vocal resonance and fremitus pass rapidly away, while there is still *dulness* on *percussion*. Now, how can this be the case if the increase of vocal resonance, etc., depends upon increase of density? We would expect the former to pass gradually away as the density diminished and percussion became normal again. In works on Physical Diagnosis, the writer has not found any explanation of these facts.

Thus we find that even in cases of pneumonia where the auscultatory signs are *typical*, the theory of "increased density, hence increased vocal resonance and fremitus," does not quite explain them.

But there are other cases of pneumonia, pure and simple, in which we find *diminution* of the vocal phenomena. In most of such cases the increased intensity of the voice, which we would naturally expect, may actually be developed by telling the patient to take a deep breath or give a cough, but in a few cases even this does not succeed in bringing it out.

These abnormal cases formed a weak spot in Laennec's hypothesis, and Skoda took full advantage of them in order to strengthen his 'consonanz-theorie.' All the upholders of the former doctrine have never explained the facts, though assertions on the subject have been plentiful and strong. One attempt at explanation was, that in these cases there were islets of un-

solidified lung tissue. This is unworthy of consideration; because if that were so, why is it that by a cough or deep breath the phenomena may be developed?

As is well known, this loss or diminution of vocal resonance may occur if the patient lie for a long time in the recumbent posture quietly. It also occurs if a plug of mucus obstructs a bronchus, but disappears when that is removed (Skoda, *op. cit.*, p. 277).

These cases of pneumonia with diminution of the auscultatory signs formed one of Skoda's most important arguments against Laennec's hypothesis, and in favour of his own; so that this offers a favourable opportunity for examining Skoda's 'consonanz-theorie.'

Shortly stated, Skoda's view of vocal resonance was, that the voice was conducted downwards by the *air* in the trachea and bronchial tubes, and resonated in those cavities, the sound being transmitted to the solid tissues further down. In pneumonia, phthisis, and other consolidations, the walls of the bronchi being surrounded by dense tissue, became better resonators than in health.

In the discussion which followed the publication of Skoda's great work, he seems to have been misunderstood. Some of his opponents thought him to mean that the trachea and bronchi responded to certain notes in the human voice because their vibration-periods were isochronous. Whether Skoda meant this by the word 'consonanz' or not, he certainly did not mean that alone, but included in the term all those reinforcements of sound which occur when a note is sounded in the vicinity of any rigid or elastic surface, especially if the surface inclose a space. Looked at from this point of view, Skoda appears to have been quite justified in assuming that the trachea and bronchi would form sounding-boards, so to speak, because of their cartilaginous rings. But where he erred, was in assuming that the bronchi became better resounders when they were surrounded with dense lung tissue. It is not the density of a substance so much as its rigidity and elasticity that make it valuable for the purpose of reinforcing sound; *e.g.*, lead, clay, or putty would make poor resonating substances in spite of their great density, while wood, light as it is, makes one of the best resonators possible (Stone, *Elementary Lessons on Sound*, 1879, p. 66).

Illustrations of this fact are not uncommon in nature; *e.g.*, when travelling in railway trains it is much pleasanter, so far as the ear is concerned, to run through a cutting made through clay than through rock, because of the great rigidity of the latter substance. That part of the Midland Railway between Appleby and Hellifield is rich in such illustrations, probably owing to the presence of the Millstone Grit.

No doubt the difficulty of transmitting sound from air to a solid body does increase with the density of that body, other things being equal; but that does not prove that such a body will throw the sound back better than another substance of less density: as a matter of fact, it will not throw it back so well if the modulus of elasticity of the lighter substance be greater than that of the denser. Now, it will hardly be admitted that if a bronchial tube be surrounded with hepatised or collapsed lung, its modulus of elasticity will be increased. We would expect that its elasticity would, if anything, be lessened.

But there is a very much more serious objection to Skoda's theory than that stated above. Even allowing that the air in the bronchial tubes did resonate better when the tube was surrounded by the dense lung, the sound has finally to be transmitted to the lung parenchyma. Now, in health this parenchyma is composed of light stretched membranes, comparatively easily set in vibration by a sound occurring in the air around them. In pneumonia or phthisis, on the other hand, the structure is a dense solid mass, which, though easily set in vibration by a sound reaching it through solid tissue, would be extremely difficult to set vibrating by a sound reaching it from the air. So that, even if Skoda were right in assuming that in consolidation the voice in the tubes was resonated more strongly in the gaseous medium, this increase would be very greatly diminished in subsequent transmission to the condensed lung, and we would have diminution of vocal resonance and fremitus in pneumonia.

No doubt, one of the reasons why Skoda's hypothesis took such firm hold was, that it explained these cases of pneumonia in which there was diminution of vocal resonance and fremitus, and which Laennec's theory, as accepted at the present time, certainly does not. In the following pages the writer will offer

an explanation of such cases without the necessity of admitting the 'consonanz-theorie,' which does not appear to be based upon sound acoustical fact.

Before leaving the subject of Skoda's theory, the writer would like to point out one fact that still further cast doubt upon its correctness. In cases of pneumonia or phthisis of the left lung, it is well known that the heart's sounds are much better conducted than during health. In this case there can be no question of resonance, because the sound is not even generated in a gaseous medium, and yet it is better conducted than in health. Skoda asserted that *hepatised* lung was a worse conductor of sound than healthy lung, and this fact proves him to have been wrong: had he merely said that the *collapsed* organ was a worse conductor than the sound one, then he would have been right.

Seeing, then, that the theory of auscultation, as at present accepted, fails to explain many of the facts met with in pneumonia, and that Skoda's hypothesis is acoustically incorrect, it remains to find out how these signs may be accounted for.

Take, first of all, a case of pneumonia in which the signs are typical, that is to say, increase in intensity of the vocal resonance and fremitus. Let it be noted, in the first place, that the elastic structures of the lung are not at all destroyed, either in the alveoli, bronchioles, or bronchi. Another important fact is, that when pneumonia attacks a lung, the chest on that side is expanded to the position of deep inspiration: this is proved by the cyrtometer (Gee, *Auscultation and Percussion*, 1893, p. 238). It follows from this that the lung structures of the affected part must be in a state of tension greater than normal, because the parietal and visceral pleura are in contact. This increase of tension refers not only, or indeed chiefly, to the alveoli, but also to the bronchioles and bronchi. So that the path for transmission of the voice to the parietes is in a better condition for transmitting sound to the stethoscope than in the healthy condition. This alone would cause increase of the intensity of the vocal resonance and fremitus, as was proved on page 203.

But this is not all. In health the alveoli contain air, so that

vibrations occurring in the solid walls of these structures will only to a slight extent be conveyed to this gaseous medium.

In pneumonia, on the other hand, the sounds conducted downwards in the walls of the respiratory tract will, when they reach the alveoli, find a substance (exudation) of nearly the same density, and vibrations will readily pass from one to the other. This will be particularly true when it is remembered that the alveoli offer a large surface to any substance contained within their walls.

From this we see that not only does the voice reach the alveoli in pneumonia with greater intensity than in health, but when it does get there a much larger mass is set into vibration, and these vibrations will easily be transmitted to the parietes and the stethoscope.

Leaving those cases of the disease in which the vocal resonance and fremitus are typical of the condition, let us consider those in which these signs are diminished in intensity, and see if there be any way of accounting for this diminution, other than Skoda's.

Gairdner has shown that in bronchitis, collapse of the lung occurs if a bronchus be obstructed by a plug of mucus, this being due to the ball-valve-like action of the plug: during expiration, air escapes from the alveoli, bronchioles, and bronchi below the site of the plug, but cannot get back during inspiration.

Lichtheim has further shown that collapse follows the obstruction of a bronchus, even when air does not escape during expiration. (*Principles and Practice of Medicine*, Fagge and Pye-Smith, 1891, vol. i. p. 959.)

If this be true in bronchitis, it is plain that there will be an attempt to bring about a similar state of affairs in pneumonia if a plug obstruct the bronchus.

In pneumonia, however, there is this difference, that as soon as the air became expelled from the bronchi and bronchioles, there would be none left, the alveoli being filled with exudation; a partial vacuum, actual or potential, would thus exist in the tubes; there is therefore no doubt that an *attempt* would be made by the exudation to leave the alveoli and pass into the bronchioles and bronchi, it being greatly assisted in this by the

vis a tergo of the elastic fibres of the parenchyma (for it must be noted that these structures are unaffected in pneumonia). The question arises whether it would be possible for a substance such as the exudation of pneumonia to be squeezed out of the alveoli in sufficient quantity to allow relaxation of their walls. In the writer's opinion, it would be possible to a certain extent. No doubt the exudation is very tough and gelatinous, still very viscid substances may sometimes be made to flow through somewhat thin tubes to fill a vacuum. Besides, there is no question that the exudation does escape from the alveoli in every case of pneumonia to a certain extent, because it is found colouring the sputum even long before liquefaction and resolution of the inflammatory products has occurred. And again, we know that on the post-mortem table the bronchioles and finer bronchial tubes "are generally found to contain fine casts of soft fibrine, as if the exudation has overflowed from the alveoli into them" (Coats' *Manual of Pathology*, 1883, p. 534). Thus it is evident that the alveoli will collapse with the extrusion of the exudation from their cavities.

But there is another form of relaxation of the lung structures which will take place without assuming the exodus of the exudation from the alveoli. During health or in ordinary cases of pneumonia, the bronchi, bronchioles, and alveoli are kept in a state of tension by the atmospheric pressure. But if a bronchus become obstructed by a plug of mucus, then the pressure, keeping all the bronchi, bronchioles, and alveoli in a state of tension, is in abeyance.

As a result of this, all these structures will attempt to satisfy their elasticity and become relaxed. If the alveoli are unable to drive the secretion out from their cavities, then they will remain tense, but the bronchioles and bronchi will certainly assert their elasticity and draw the lung in *en masse*, thus becoming relaxed. This relaxation of the tension in the walls of the tubes must, of course, be followed by a great diminution in their power of conducting sound; and as a result, a loss instead of an increase of vocal resonance and fremitus will occur.

Which of these two explanations of the loss of vocal resonance in cases of plugging of a bronchus, is the correct one,

it is difficult to say, and the answer will depend upon the extent to which the exudation may be driven out of the alveoli. In the writer's opinion, both processes may occur,—relaxation of the walls of the alveoli, and also of the bronchioles and bronchi: as will be seen in the case of chronic bronchitis, both processes do occur under the same conditions (page 229).

But there are cases of pneumonia in which diminution of the vocal signs takes place without the occurrence of obstruction of a bronchus by a plug. If a patient with pneumonia lie quietly for some time in the recumbent posture, and without coughing, a diminution in the intensity of the thoracic voice is often noticed; but this loss can generally be made to disappear, and be replaced by increased intensity, if the patient be told to give a cough or take a deep breath. Even in the limited experience of the writer, such a case occurred.

It must be admitted that it is not every case of pneumonia that can be made to demonstrate the above phenomena, but only occasional ones. Such abnormal cases may be explained in the following way:—

During health the lung is kept in its normal tension by the pressure of the air on the surface of the alveoli; and while the organ is healthy this pressure is far more than sufficient, being a much stronger force than the elasticity of the alveoli, bronchioles, and bronchi, which is continually attempting to produce collapse of the organ. Thus all the structures of the respiratory organs are kept in a continual state of tension, varying during expiration and inspiration. When the alveoli become filled with exudation, it is plain that the atmospheric pressure keeping the organs tense must be very much less than in health, because the area on which that pressure is exerted is much less; in fact, the pressure is now represented by the sum of the transverse areas of the bronchioles at which the effusion ceases, which is a very much smaller surface than the sum of the areas of the corresponding alveoli. This pressure in ordinary cases of pneumonia is, however, still sufficient to keep the lung in its state of tension, especially if strong respiratory efforts or violent coughing occur. But it needs no very great step of the imagination to conceive that during a period of quiet respiration in the recumbent posture this state of matters might become altered;

especially as the natural elasticity of the thoracic parietes would to a certain extent help the elasticity of the lungs themselves in their progress towards relaxation, and the driving of the secretion from the infundibula and bronchioles further upwards into the bronchi. Again, it must be noted that the further up the bronchi the secretion extends, the less does the atmospheric pressure amount to, because the transverse areas of a bronchus is less than the sum of the transverse areas of the smaller bronchi in connection with that bronchus. Thus, the further up the tubes the secretion extends, the more relaxed may the bronchial and pulmonary structures become, and produce a diminution in the intensity of the vocal resonance and fremitus. (See note, later.)

If, however, the patient gives a cough and drives the secretions out of the tubes and expectorates it, or if he takes a deep breath and sucks it back, it is easy to see that at once the tension will again be raised to the normal or above it, and hence an increase in the vocal signs will be perceived in accordance with the explanation on page 218.

It appears to the writer that the explanation given above accounts for the changes in vocal resonance and fremitus occurring in pneumonia. It accounts for those cases where there is diminution in the intensity of these sounds, which Laennec's hypothesis certainly does not: not only so, but it enables us to dispense with Skoda's theory, which is acoustically wrong.

Thus it will be seen that the writer agrees with the usually accepted theory to this extent, that if the alveoli become filled with semifluid or solid substance, as occurs in pneumonia and phthisis, and the other factors remain unchanged, there will be an increase in the intensity of the auscultatory signs. But a most important condition is attached thereto, viz., that the tension on the alveolar walls, bronchioles, and bronchi must either be maintained or increased: if relaxation of any of these structures sets in, then diminution of the vocal resonance and fremitus occurs.

Phthisis Pulmonalis.

To a certain extent the pathological process in this disease produces a condition somewhat similar physically to that

occurring in pneumonia. The inflammatory products collect in the bronchioles and alveoli as they do in pneumonia; there is no collapse of the structures, and the elastic fibres show a great power of resisting the destructive process; but besides this, there is produced a certain amount of thickening and induration of the walls of the alveoli and bronchi.

In the fibroid form of the disease the walls of the bronchi are chiefly affected, "the inflammatory products going on to the formation of dense connective tissue. Trabeculae of firm tissue pass in from the thickened pleura, and run inwards towards the root of the lung. Compensatory emphysema occurs in parts, for by the *tension* and *contraction* of the connective tissue some alveoli are destroyed, and others dilate to fill up the space" (Coats, *op. cit.*, p. 550).

In both caseous and fibroid forms pleuritic adhesions occur, and drag in the wall of the thorax, producing the flattening of the apex so marked in this disease; the new-formed tissue also drags out the bronchial wall (Coats, *loc. cit.*, p. 551).

As the caseous form goes on to liquefaction, the resulting products are expectorated and a cavity is formed; the *walls* of the cavity being still in a state of condensation, and their alveoli filled with the inflammatory products of the disease.

Turning to the physical conditions present, it will be seen that there is no collapse of the lung structures, but there is increased density. As regards tension, it will be seen that this is not increased as far as the *normal tissues* of the organ are concerned. But in phthisis we have to deal with structures other than the normal ones, viz., those that result from the organisation of the inflammatory products. As was noted under the pathological conditions, the connective tissue new formed is often in a state of great tension, so much so that it is able to drag the thoracic walls inwards and the bronchi out: this must surely be a tension of considerable magnitude!

When the disease goes on to liquefaction a cavity is formed: when this occurs, it is evident that the atmospheric pressure acting upon the affected part of the lung is much greater than before, because the area of the cavity is much greater than the transverse areas of the bronchioles or bronchi leading to it (it is assumed, of course, in this case, that the cavity is in communica-

tion with the air by a bronchus, no matter how small). This does not necessarily mean that the *tension* upon the walls of the cavity will be increased; it probably will cause an increase of that tension, but not necessarily; because the walls may be sufficiently supported by the surrounding tissues to resist the pressure, just as the bladder of a football is supported by the leather case after it has reached a certain state of distension.

If, however, the cavity be not in communication with the open air, then no doubt relaxation of the walls would to a certain extent occur; but it is highly improbable that this relaxation would be complete, because, as some of the adhesions became relaxed, others would become tense by the mere alteration in the position of the parts.

The intensity of the voice heard over a phthisical consolidation or a cavity is almost always greater than normal. In the case of cavity this increase is often exceedingly great, and forms the pectoriloquy of Laennec. This great investigator, indeed, considered it, when typical, to be pathognomonic of that condition: experience has since shown that this is not correct; still, the occurrence of this sign is very suggestive of vomica. Now, the very fact of the vocal resonance increasing as excavation proceeds seems to the writer to militate against the usually accepted theory of increased density. The tissues cannot in any sense be denser after excavation than before; as a whole, the affected part is less dense, because a large portion liquefies and is expectorated; even that portion of the fluid which is not expectorated falls to the lowest part of the cavity, which is the position furthest away from the stethoscope if the patient be in the recumbent posture.

As will be noted on referring to the Clinical Investigation (page 202), the tuning-fork placed in the middle line of the body, no matter whether it be on the larynx, trachea, or sternum, is heard best over the diseased area. In this respect phthisis differs from pleurisy, the reason of course being, that in the latter disease, as was before shown, the lung is relaxed, and is a worse conductor than the healthy organ, while in phthisis it is not collapsed, but denser and more tense, and hence a better conductor. So also with the heart's sounds: they are conducted better through a phthisical than through a healthy or collapsed organ.

The writer's explanation of the auscultatory signs found in phthisis is similar to that which he has given in pneumonia, viz., that there is an increase in the density of the structures, as also in the tension; but the increase of the tension occurs rather in the new-formed tissue than in the normal lung structures. In phthisis there is often an emphysematous condition present, compensatory or complementary in character. It will be noted, in speaking of emphysema (page 225), that this disease causes diminution in the auscultatory vocal signs. Now, in phthisis this diminution would also occur were it not for the fact that, besides the emphysema, there are trabeculae of tense tissue, which conduct the sound from the bronchi to the parietes, and hence cause increased vocal resonance.

Before leaving the subject of phthisis, the writer would like to point out one matter on which most physicians would probably agree, viz., the intensity of the vocal resonance and fremitus in phthisis is not nearly so liable to sudden changes as sometimes occur in pneumonia. The patient may lie quiet for any length of time in the recumbent position, but the voice heard over the thorax is still louder than normal. It is astonishing with what regularity and persistence the thoracic voice is increased in intensity in phthisis, while in pneumonia it not uncommonly varies. According to the writer's view, this persistence is easily explained. The structures are kept tense, not only by the pressure of the atmosphere as in pneumonia, but also by *adhesions*; hence, even if atmospheric pressure be suspended, as it often undoubtedly is, there may still be no diminution of the vocal resonance and fremitus. The writer does not hold that a diminution never does occur in phthisis, but that it is rare, and that for the reason just given.

In regard to phthisis, as indeed to other diseases, it must be remembered that the organs, as seen at the post-mortem, can in nowise be considered in the same *physical* condition as that in which they exist during life: *e.g.*, a cavity, as seen in the lung of a patient dead from phthisis, has been allowed to collapse on opening the thorax, and again on opening the cavity itself, besides the fact that adhesions are necessarily stript from the parietes.

Emphysema.

The anatomical changes found in this disease may be briefly summarised as follows:—

“The partitions separating the alveoli atrophy, and the infundibulum expands into a simpler cavity The infundibulum continues to expand, and meets with other infundibula undergoing a similar process. By mutual pressure the adjoining tissue atrophies and the two communicate. The larger cavity tends to become simpler by atrophy of all partitions and septa, and so the process goes on. *Of most importance is the atrophy of the elastic tissue*, because on this account the lung tissue will be prevented from collapsing as it normally does” (Coats, *op. cit.*, pp. 517 and 518). This latter fact is well known to all physicians, because, when the thorax is opened at the post-mortem, the emphysematous lungs collapse very little, or not at all. Could any further proof be desired to show that the organs in this disease are in a state of little or no tension?

Vocal resonance is much diminished in emphysema, and tactile fremitus is often absent. This is exactly what would be expected if the view held by the writer be correct, viz., with decrease of tension there will be a diminution of the sound-conducting power of the structures.

Now, the upholders of Laennec's theory may say that there is also decrease of density in this disease. That is quite true; nevertheless these writers will have to adopt a different line of reasoning than that they have hitherto used, viz., the sound is conveyed better through condensed than through normal lung, because it is *more homogeneous*, and hence there is not so much sound lost. ‘In emphysema, also, the lung is more homogeneous, and there is also less loss of sound by reflexion than in the healthy condition; *e.g.*, where 100 alveoli previously existed, 50 now remain. So that, according to this view, we would expect either undiminished or increased vocal signs. Thus it is evident that even if the commonly accepted hypothesis were correct, the reasons given in support of it are certainly incorrect. It appears to the writer, however, that the facts are explained perfectly by the loss of tension in the structures.

Changes in the Intensity of Auscultatory Signs not necessarily significant of Disease.

In the foregoing pages consideration has been directed to the changes in the intensity of the auscultatory signs noticed in disease. But a great deal of light may be thrown upon the subject by differences noticeable in the healthy lung.

(1) *Age*.—This appears to have a considerable effect upon the sound-conducting power of the lung.

We cannot compare the vocal resonance and fremitus of the child with that of the adult, for the obvious reason that the child's voice is much weaker and more highly pitched than that of the latter; but the intensity of the respiratory murmur gives us a good comparison. In the child this sign is found to be much louder than in the case of the typical adult: so much is this the case, than when in an adult it is very loud, as sometimes occurs in disease, it is spoken of as 'puerile.' To what cause can this be ascribed? It cannot be on account of any difference in the density of the lungs, for the adult's lungs are as dense as the child's. Neither will Skoda's theory of resonance account for it, because there is as much possibility of resonance occurring in one case as the other. But a difference in the elasticity of the lungs will completely explain the matter.

The exceedingly elastic lungs of the child are, by very reason of their greater resiliency, kept in a state of greater tension than the adult's, and this at once explains the greater intensity of the respiratory murmur in their case.

Again, as old age approaches, it is very well known that the vocal resonance and fremitus as well as the respiratory murmur usually become rather diminished in intensity. Here, again, both Skoda's theory of consonance and the usually accepted theory of differences in density are quite incompetent to explain the facts. They are quite explained, however, by differences in the elasticity and tension of the structure of the lungs; for it is an undoubted fact that even in healthy old people senile changes are apt to occur in the lung tissue in common with the other organs of the body, and that these changes are in the direction of atrophy of the tissue, similar to that occurring in emphysema (Coats, *op. cit.*, p. 521).

(2) When a healthy individual is suddenly struck down by an acute unilateral pleurisy or pneumonia, the unaffected lung does compensatory work, sometimes even enlarging its boundaries and extending across the middle line. In these cases it is usual to find the respiratory murmur increased in intensity, even to the degree known as 'puerile.' How can this fact be explained except by increased tension, which must certainly take place if a lung is called upon *suddenly* to do compensatory work? As before, Skoda's theory and that usually accepted fail to explain these facts.

It is interesting to compare this case when the lung tissue is healthy and becomes suddenly enlarged, and hence *more tense*, with that which occurs when the organ becomes gradually enlarged and *more relaxed*, as in emphysema arising from chronic bronchitis: in the former case, the respiratory murmur is greatly increased in intensity, while in the latter it is not so loud as normal.

This well-known fact, that when a lung is called upon suddenly to do compensatory work the respiratory murmur is louder than normal, should be taken in conjunction with another fact demonstrated on page 203, viz., that the sound of a tuning-fork is conducted through the lungs better when the organ is in the position of inspiration, than when it is more relaxed at the end of expiration. In both cases there appears to the writer no other explanation than difference of tension upon the structures.

(3) Even in perfectly healthy individuals of the same age, all physicians know that the loudness both of the vocal resonance and the respiratory murmur, as well as the intensity of the vocal fremitus, vary within wide limits. Is there any way of explaining this fact? It is out of the question to suppose that it can be accounted for by differences of density or of resonating power of the respiratory organs. As in the two preceding cases, so also here these difficulties at once disappear if we take differences of tension into consideration.

In Pye-Smith and Fagge's *Principles and Practice of Medicine*, 1891, vol. i. p. 967, are to be found some interesting paragraphs on the predisposition to emphysema; some families being peculiarly liable to the disease, even without any known cause. Cohnheim, it is stated, regards it as an undoubted fact that this

is due to a congenital deficiency of the yellow elastic fibres of the alveoli.¹ Whether Cohnheim and others are right in this respect or not, there is no doubt whatever that the elasticity of the lungs varies greatly in different individuals (Perl's vol. vi., *Deutsches Archiv*), and hence that differences in the tension of the organ must also exist.²

This being so, we are completely able to explain variations in the loudness of the thoracic voice, the respiratory murmur, and intensity of the vocal fremitus, by differences of tension.

Thus we find that the auscultatory signs both of the voice and the respiration vary considerably, even in healthy lungs, according to (1) their age, (2) their degree of distension, and (3) their varying structure in different subjects; we find, further, that these differences of the physical signs are quite unexplained by the theories of resonance, or of differences of density or homogeneity. On the other hand, differences of tension explain them all completely.

The Effect of Plugging of a Bronchus in Bronchitis.

A bronchus may become obstructed in several ways, sometimes by the growth of a tumour or by pressure from without, or it may occur, as Gairdner pointed out, by a plug of mucus. This is most liable to occur in bronchitis.

Obstruction of a bronchus, from whatever cause, is followed by a great diminution of the vocal resonance and fremitus, or even by the total suppression of these signs (Bristowe, *Theory and Practice of Medicine*, 1887, p. 388. Finlayson's *Clinical Manual*, 1886, p. 639).

Skoda knew the importance of this fact, and made a great deal out of it to support his 'consonanz-theorie.'

Laennec could not be right, he argued (*op. cit.*, p. 35), because, though the lung be hepatised, yet if plugging of the bronchus

¹ Cohnheim, *Vorlesungen über Allgemeine Pathologie*, 1880, IIte Band, p. 192. "Deshalb möchte es vielleicht auch nicht völlig ausgeschlossen sein, dass hier individuelle Differenzen im Mass der Lungenelasticität im spiele waren . . ."

² See also Perl's *Lehrbuch der Allgemeinen Pathologie*, Ite Theil, pp. 261, 262, and 263. On the latter page he demonstrates that the power of retraction of the lung as it exists in normal healthy chests varies between 50 and 78 mm. of water pressure. Hence it is evident that the *tension* must vary in the same proportion, which is very considerable.

occurred, the vocal resonance and fremitus became diminished. There is no doubt that Skoda proved the accepted theory to be wrong, and no upholder of it has been able to explain this fact in connection with plugging of a bronchus.

Although Skoda completely proved the insufficiency of the accepted theory, yet he did not prove his own to be correct; because, either he was ignorant of the fact, or else he neglected it, that plugging of a bronchus was followed by *collapse*, either in the manner pointed out by Gairdner or Lichtheim (page 218).

This fact only goes to prove further the incorrectness of the accepted theory; because, as collapse proceeds in a lung previously containing air, it is evident that the density and homogeneousness of the organ increases, and hence we would expect increased intensity of the vocal resonance and fremitus, which is not the case.

On the other hand, we have already seen very many objections to Skoda's theory itself; and hence it would be wise to see if there is no other way of accounting for the loss of vocal resonance after plugging of a bronchus.

Looked at from the writer's point of view, the whole difficulty is cleared up at once in a satisfactory manner. The moment that a bronchus became completely obstructed, relaxation and collapse would begin at once in all the structures below. If the process occurred in the manner suggested by Dr Gairdner (the ball-valve action of a plug), the resulting collapse would take place very rapidly. In cases in which the obstruction prevented both entrance and exit of air, then the process would take somewhat longer to complete (Fagge and Pye-Smith, *op. cit.*, vol. i. p. 959); but even here the relaxation would be much more rapid at its commencement, because the gases are absorbed under the greatest pressure the moment the obstruction takes place.

In pneumonia, the same process was described as that related above (page 218), and in both cases it appears to the writer that the explanation offered accounts for the facts just as well as Skoda's theory, and is *acoustically* indisputable, because no one can deny that diminution of tension in any resilient body will seriously impair its sound-conducting power, as was pointed out on pages 204 and 211.

Summary of the preceding pages as regards Intensity of the Auscultatory Signs.

In the preceding pages the conditions which cause alteration in the *intensity* of the vocal resonance, etc., have been considered. Before passing on to considerations as to the alterations in *quality* of the auscultatory signs, the foregoing results might be summarised.

(1) It has been shown that neither Skoda's theory of increased consonance, nor the usually accepted theory (Laennec's) of increased sound-conducting power of condensed lung, will account for all the phenomena of increase in the vocal resonance.

(2) Facts have been demonstrated which are entirely opposed to either of these two theories.

(3) It has been shown that not only would we expect to find that alterations in tension would affect the intensity of the auscultatory signs, but that they do so to a very great extent.

(4) Whenever there is increase in the tension of the tissues forming the respiratory organs, there is increase in the intensity of the auscultatory signs; and whenever there is a decrease in the tension, these signs are diminished. This statement holds true both in health and disease: it explains individual differences of the vocal and other phenomena, besides a number of other facts which are quite inexplicable either by Skoda's theory or that of Laennec.

The writer is not aware of any fact which can be said to be incompatible with the above statement, nor can he find any such in works on Physical Diagnosis.

It might be urged further, in favour of the views put forward by the writer concerning the inferior sound-conducting power of lung which is collapsed, compared with that which is distended as in health, that the facts found at the bedside are more in accordance with the writer's views than with those at present mostly accepted. Thus, whenever collapse really does occur, whether it be from fluid in the pleural cavity or from pus or air in that cavity, or if it ensue upon the plugging of a bronchus by a plug of mucus, or, again, if it be due to a tumour growing in the thorax, and allowing the lung to collapse because of the

space occupied by the growth, the vocal resonance and fremitus and respiratory murmur are in the great majority of cases very much diminished. Not only are these facts, but they are universally admitted as such by physicians. Very significant, then, are the excuses brought forward by writers to account for these cases where the theory fails; as thus:—in pleurisy, although collapse occurs, the vocal resonance and fremitus are greatly diminished because of *the layer of fluid*; when the collapse is due to obstruction of a bronchus by a plug of mucus, *this plug of mucus* is used as the excuse, there being no layer of fluid in this case; if the collapse be due to a *tumour*, the theory is very often forgotten; or if not forgotten, some vague excuse is again put forward, such as that a tumour often causes obstruction of a bronchus, or the accumulation of fluid in the pleura; the fact that a tumour very often does neither of these things being quite ignored. By subterfuges like these, the theory is excused, an apology being put forward to account for its failure in each case in which collapse occurs, according to the author's fancy, until, like Mahomed's swine, "from head to tail 'tis eaten."

It appears to the writer that a better course to follow would be to take our stand upon what both experiment and clinical observation show to be true, viz., that collapsed lung is a worse transmitter of sound than the normal distended organ. Such a course would enable us to dispense entirely with the excuses exemplified above, and whose very variety casts doubts upon the theory which they are meant to support.

The writer does not hold that bronchophony and bronchial respiration may not be heard over a collapsed lung. On the other hand, it will be shown later that it is quite possible that the voice and the breath-sounds heard over such an organ may possess the *quality* of those sounds as normally heard over a bronchus; but, no matter what the quality of the sound heard over the collapsed organ may be, its *intensity* will be less than that heard in health. (Cases in which the organ, though collapsed, is rendered tense by adhesions, are of course excluded.)

Bronchophony and bronchial respiration are usually heard in health over the interscapular region behind and over the main bronchi in front; therefore, when collapse occurs, and these signs

are heard at the parts mentioned, their presence is *not* due to the collapsed lung, as some writers seem to think. Skoda pointed out that we are unable to make any deductions from the character of the auscultatory signs of the voice and respiration heard over these parts (Skoda, *op. cit.*, p. 80).

There is one condition of a collapsed lung which has not hitherto been considered. If such an organ be subjected to excessive pressure from fluid in the pleura, it is evident that it might again become possessed of a certain amount of tension by the pressure exerted upon it, just as cotton-wool may be rendered tense by pressure of the hand. Whether this tension by compression is ever sufficient to cause an increase of the vocal resonance it would be difficult to say. It must be very uncommon, even if it occurs at all; because, no matter how great the amount of fluid effused may be, the vocal resonance and fremitus are seldom increased in pleurisy; and even if they are, there remains the possible or even probable fallacy that such increase may be due to adhesions, rendering the organ tense, and not to the excessive pressure.

(*To be continued.*)

THE GENESIS OF VOWELS. By R. J. LLOYD, D.Lit., M.A.
(PLATE IX.)

THE movable units of which the sounds called words are composed may be called *phones*. They correspond, roughly and inaccurately, to the letters of the written word. If classed according to origin, they fall into three classes: (1) those which originate entirely from the larynx, such as *e*, *o*, or *n*; (2) those which originate entirely from some percussion or friction in the voice-passage, while the larynx stands open and idle, such as *p* or *f* or *s*; (3) those which spring from both of these sources simultaneously, such as *b* or *v* or *z*. Taking the word *stoma* (*στόμα*, mouth) to signify the passage leading from the larynx to the outer air, these classes may be called (1) glottal, (2) stomatic, (3) glotto-stomatic.

But phones are also divided according to their function in language. A phone which either by itself constitutes a syllable, or is the strongest phone in a syllable, is called a vowel. The weaker connective phones are called consonants. This classification is not strictly acoustic, but linguistic; and it varies somewhat from language to language. In the English words *able*, *bitten*, *paddled*, *hadn't*, *l* and *n* are really vowels, and there is hardly any phone which does not, in some locution of some language, function as a vowel. Nevertheless there are certain phones which are more fitted, by their own nature, to perform this function than any others. The essential distinction between vowel and consonant is that of superior sonorousness. The phones which are pre-eminently vowels are simply the strongest phones. Now, all the stomatic phones are weak, because the larynx does not co-operate in them at all; and the glotto-stomatic phones are not strong, because the larynx only co-operates feebly. The only class of phones which make really good strong vowels are the purely glottal class. In all of them the chords vibrate freely and strongly, because the air is not obstructed in the stoma. But the sound is more easily obstructed than the air is. Any one may observe for himself that in quiet

breathing one nostril is sufficient to carry the breath without phonic friction, *i.e.*, friction loud enough to serve as an audible element in speech. But the glottal sounds which issue through two nostrils (*m*, *n*, and *ng*) are nevertheless too weak to make very good vowels. For similar reasons, the sounds *w*, *y*, *l*, and untrilled *r*, though all purely glottal, are not good vowels. Hence the frequent classification of all these sounds by grammarians as semi-vowels.

But, eliminating these, it may be laid down as a general principle that every glottal phone possessing a sufficient exit is a good usable vowel. Yet even here there are immense differences of usefulness. For the usefulness of a vowel depends also upon its distinct phonic character; and this distinct phonic character is only possessed by a limited number of vowels, each of which is found to possess a distinct type of stoma. Seven of these leading types exist as long vowels in English, and their articulations are shown on the accompanying diagram. A key-word containing the vowel in question is there attached to the figure of each articulation, and the vowel itself is indicated in bolder type. For convenience of comparison with other languages, key-words have been chosen which exhibit the symbols *A E I O U* in values usual abroad rather than with us (Plate IX.).

But when a singer, for example, does not desire to utter any vowel in particular, but simply to emit tone from the larynx through an open voice-passage, the sound is, of course, according to the above definition, vocalic, but the vowel produced is neither *a*, *e*, *i*, *o*, *u*, nor anything like them. It resembles much more the *u* in *but*. The same sound is sometimes heard as an interjection when the larynx is set to work by surprise. Sweet symbolises this vowel by inverted V (Λ), and calls it unmodified voice. And when the definite articulations proper to the definite vowels are not properly carried out, a similar result follows. Consider the sound which is given in rapid speech to the *ä* in *about*, to the *ě* in *society*, to *ȳ* in *charity*, to *ø* in *consist*, and to *ŷ* in *educate*. When these are carefully listened to, they are found to possess a much greater resemblance to each other, and to Λ , than they do to any kind of *a*, *e*, *i*, *o*, or *u*. It is therefore only when certain distinct types of stoma are framed that vowels of distinct phonic character are produced. Such vowels

are naturally far more useful than the feebly differentiated vowels of all other articulations. They are therefore the dominant types in language, and the most important objects of study. This is shown by the fact that no language dispenses with them, though the *i* and *u* classes are naturally, by reason of their small exits, inferior in sonority to the *a* class. Whenever a human being executes the articulation depicted in one of these diagrams, he produces the vowel belonging to it. If the shape of the articulation is correct, the size does not matter. In a paper read before the British Association at Cardiff in 1891, I summed up this truth in the law, "*Like articulations produce like vowels.*" This dictum is now accepted with practical unanimity by phonetic observers, but I have had to defend it from strong attacks by acousticians, notably Dr Pipping of Helsingfors and Prof. F. Auerbach of Jena; because it carries with it the theory of vowel-sound which I advanced in the same paper, namely, that each definite vowel possesses more than one stomatic resonance, and that its identity is due not to the absolute pitch of these resonances, but to their mutual relation, or interval, or ratio.

But the converse of this law is not strictly true, and its limitations are worth noting. We are compelled to produce like vowels very often by somewhat, though not altogether, unlike articulations. Two individuals sometimes differ so far in organic endowment that they are physically incapable of producing articulations accurately corresponding in figure, each to each. But there is still a strong general resemblance, because the aim of both is to divide and shape the stoma in such a way as to produce the same relation between its resonances. But the most interesting thing to be noted here is that in the same individual the available stoma is not always the same in actual speech and song. This is especially true of the 'expansible' series *ɛ*, *æ*, *a*, *ā*, *ɔ*, to which our three middle diagrams belong (Plate IX.). There is not always time or convenience to produce a desired vowel articulation in its most expanded and sonorous form. The maximum of this difficulty occurs when the vowel (1) is closed at both ends by a plosive or fricative consonant, (2) is short by nature, (3) is spoken or sung at a high speed, and (4) at a high pitch. Such a combination of circum-

stances reduces the practicable size of the stoma in every vowel, but especially in those just indicated. In every syllable composed of a vowel between consonants there are really five elements,—the vowel, the two consonants, and the glides connecting the vowel with each consonant. This may be clearly seen in the phonograms, and these glides constitute a considerable fraction of the syllable, for its whole duration is commonly not more than one-third of a second. They are longest, both in space and time, when the distance between the vowel position and the consonant position is greatest, *i.e.*, when there is a glide from a very close consonant to a very open vowel. They become relatively longer when the vowel, either through its occurring in a short syllable or through its being spoken with greater rapidity, becomes shorter. The vowel would in these cases be largely obliterated by the glides, unless some means were used to shorten the latter. The instinctive remedy is to compress the configuration by partly closing the jaws, so that the parts are brought nearer together. The internal organs are at the same time rearranged so that the due proportion of parts is still respected, and the same vowel is still produced. The inevitable result of this compression of the stoma is to raise the pitch of its resonances. Observation of the *a* vowels, coupled with a study of Boeke's phonograms of Dutch *aa* (*Pflügers Archiv*, vol. 50, p. 312), led me to conclude that this rise may amount to 4 semitones in a long closed syllable. It must be still greater in a short closed syllable. These facts tell decisively in favour of the theory here defended,—that the cardinal vowels are created by the relative pitch of plural resonances.

Like results occur, on a smaller scale, when a vowel is sung at unusually high pitch. The tension of the muscles inside the larynx is then so great that the opposing extra-laryngeal muscles must be brought into play to support the cartilages of the larynx. These muscles, in their turn, pull strongly upon the tongue-bone and lower jaw, and tend to draw the whole larynx outward and upward. But the larynx is at the same time held downward and backward by attachments of elastic tissue, which support the cartilages on the opposite side. These attachments, however, not being muscular, give way in proportion to the pull which is exercised upon them, and this pull increases and

decreases with the pitch of the note. Outwardly this action produces the rise and fall of the Adam's apple which is so noticeable in some speakers. Inwardly it produces very rapid changes in the bulk of the stoma. The higher the note, the smaller the stoma, and the higher its several resonances. The greater part of this rise in pitch of resonance takes place in the upper half of the register. It can be shown to reach 2 or 3 semitones on very high notes.

It generally happens that sung vowels are inferior in clearness of vocalic quality to spoken or whispered vowels. On high notes this may be partly attributed to the state of muscular tension above described, which deprives some of the organs of the flexibility needed for perfecting the required configuration of the stoma. This goes to explain the frequent very bad quality of high sung vowels, but the inferior distinctness of all sung vowels rests upon more general grounds. Vowel quality is entirely created by the resonances of the stoma. Therefore the conditions of strong vowel quality and the conditions of strong resonances are identical. Now, the condition of strong resonances is the presence of an appropriate stimulus, and that stimulus is in every case afforded by the larynx, but in widely different degrees. The singing larynx is adjusted to the production of a given musical note, as free from other noises as it can be made. But in the speaking larynx there is purposed collision (see Helmholtz, *Sensations of Tone*, p. 104), producing frictional and percussive noises, and giving to the spoken tone its characteristic roughness; whilst in the whispering larynx, tone disappears, and there is nothing emitted from it but frictional noise. Of these three states of the larynx the one which affords the least stimulus to resonances is undoubtedly the singing state. A tone of a certain pitch can excite a resonance of that pitch, and no other. A very pure vocal note contains very little indeed except vibrations of a certain tone, and of certain multiples or upper partials of that tone. The chance that for any given vowel the singer will use a note just suited to excite one of its resonances is slender, and the chance that any element of the same note would at the same time precisely arouse a second resonance is very minute indeed. The power of exciting vowel resonances which a sung vowel possesses proceeds chiefly,

therefore, from that small residue of frictional noise from which it cannot possibly free itself. So minute, relatively, and so distributed is this element of the sung vowel, that we search for it in vain in phonograms. Still, it is perfectly evident that air cannot be forced through a chink so narrow as the glottis without friction; and it is the property of resonant cavities to multiply the feeblest stimulus very rapidly. But in spoken and whispered vowels aerial friction is designedly produced. The mixed and miscellaneous vibrations set up by this friction are ready and able to afford stimulus to every kind of resonance; so that whatever the size and shape of the stoma, its resonances never fail, either in speech or whisper, to be adequately stimulated.

A few details of vowel production remain to be noticed. For a good vowel, it is necessary, as already stated, to avoid friction in the stoma or voice-passage, whilst somewhat cultivating it in the larynx. In some vocalic stomata there are narrow passages, which would be frictional if they were not carefully shaped. If a passage must be of a certain capacity or cross-section, it will set up the minimum of friction the nearer it can be made to approach to a cylindrical form. Hence the rounding of the lips for a very close \bar{u} , and the hollowing of the tongue for \bar{i} . The uvula seems to have an important office of this kind in all the a , o , u (technically called the *back*) vowels. There would be in these cases great danger of aerial friction between the velum and the tongue-back if the uvula did not bisect the passage, and convert the narrow intervening slit into two relatively round openings, resembling nostrils.

The nose sometime plays an unsuspected part in the production of vowels. Its participation is detected by holding a cold mirror under the nose during the speaking or singing of a vowel. A slight nasality is thus found to be very common, but it is with difficulty recognised as such by the ear. The acoustic effect of a slightly opened nose is simply to add to the other resonances the resonance proper to the nose, as an open tube. I determined this resonance by direct measurement and observation (*Phon. Stud.*, iv. p. 287) to be in myself a^3 (1760 V D) to C^4 (2112 V D) according to the position of the velum. These figures are closely confirmed by one of Hermann's phonograms (*Pflügers Archiv*, vol. 47, plate 8, fig. 7).

The trachea or windpipe forms a considerable air-space below the larynx; and the examples of fricative consonants such as *f* and *s* show that very audible resonances can issue from an inner cavity through apertures quite as narrow as the glottis; yet the evidence of any effective resonance proceeding from the trachea is still to seek. The trachea divides at its lower end into two bronchi of unequal length. It is possible that this inequality operates to produce interferences which render the whole tube incapable of strong resonance. Even then it may lend a certain support to the larynx when vibrating about its own pitch. In phonograms sung between 300 and 400 V D, I have noted, oftener than elsewhere, a preponderating strength of the fundamental tone. Here, too, in singing up the scale, the 'chest' voice changes into the 'head' voice. The motive of this nomenclature may have been that here the resonance of the trachea is felt to fail. It will be seen, too, in analysing phonograms, that a resonance 300 to 400 V D appears in all the *a* vowels,—German, Dutch, and Swedish alike. It is possible that the *a* articulation gives special facility to the exit of the resonance of the trachea.

THE INTERPRETATION OF THE PHONOGRAMS OF VOWELS. By R. J. LLOYD, D. Lit., M.A. (PLATE IX.)

WHEN it is attempted to study vowels by any phonographic method, some notable differences between sung, spoken, and whispered vowels are brought to light. The whispered vowel is so weak that it does not yield serviceable phonograms at all. No investigator has yet published or attempted to analyse a whispered vowel-curve. The spoken vowel yields well-marked phonograms, and so does the sung vowel, but with a remarkable difference in form. When we sing the vowel *a* to the note *c* the resulting phonogram contains two sets of vibrations—(1) those of the tone *c* and its upper partials, issuing from the larynx; (2) those of the stomatic resonances which characterise the vowel *a*. A further complexity arises from the fact that these two factors influence each other,—those partials of the glottal note which coincide closely enough with the resonances of the voice-passage or stoma being naturally much exaggerated by the latter. Individual voices differ in their endowment of upper partials: so does even the same voice at different times. But so long as the same vowel is steadily sung at the same pitch by the same person at one period of time and is phonographed by the same instrument, the conditions are uniform and the results are beautifully regular. The larynx of a good singer pulsates with the regularity of a tuning-fork; and if the articulation of the vowel be well held, its phonogram is simply a repetition of similar curves, one for each pulsation of the larynx. To the eye this similarity is generally perfect, and the most careful measurement of different waves usually reveals only slight differences. For the glottal note is not only the most powerful element in the vowel, but it is commonly of a much deeper pitch than the stomatic resonances by which it is modified. Male speech is mostly carried on between 100 and 150 V.D. per second, male song between 80 and 400 V.D., but male resonances range, as far as at present discovered, from below 300 to above 3000 V.D. Consequently most resonances commonly repeat

themselves several times in the course of one glottal period. Two waves are shown in our diagram (Plate IX.), much magnified, of Pipping's Finno-Swedish *e* (resembling our *e* in *rein*), sung at 258 V.D. per second. The most prominent resonance of *e* is just about nine times as rapid as this; consequently the ninth partial of the glottal tone is greatly magnified. To the unaided eye each period seems to consist entirely of one large fundamental wave crossed by a set of minor waves nine times shorter.

But regularity of this kind can manifestly only occur when the resonance is a nearly exact multiple of the glottal tone. Suppose that while the above vowel was being sung, the sung note had been raised half-a-tone. The resonance would then have been only $8\frac{1}{2}$ times as frequent as the glottal pulsation. The effect which follows in such a case is that the ninth partial is still magnified, but not so strongly: and the eighth partial is magnified too. Moreover, in the phonogram these two partials interfere with one another, so as to form that kind of crescent and decrescent curve which graphically represents a 'beat.' Such a curve, superposed upon a strong fundamental, may be seen in Pipping's phonogram of Finno-Swedish *i* (very like French *i*) sung at the pitch of 261 V.D. Two waves are here given.¹

But in speech that steadiness of glottal vibration which is the property of well-sung vowels vanishes completely. The pitch is constantly sliding up or down, so that the consecutive waves are continually changing in length, and therefore, as we have seen above, in shape also. Hence it is often difficult to say exactly where one wave ends and another begins; and consequently investigators hitherto have studied sung phonograms much more than spoken ones. It can hardly be doubted, however, that this instability of pitch in the spoken vowel is a further cause of its superior distinctness to the auditory sense. In the plexus of vibrations, which is presented by a spoken vowel to the ear, the resonantal phenomena are caused to stand out more strikingly from the glottal phenomena, because the latter are always changing whilst the former remain sensibly the same.

The study of phonograms enhances the conviction of the

¹ *Om Klangfärgen hos sjungna Vokaler*, p. 95. See also *Zs. für Biologie*, vol. xxvii. p. 1, and xxxi. p. 524.

enormous analytic powers of the ear: it at the same time emphasises the helplessness of the eye in detecting the real meaning of the phonograms. A vowel phonogram which is taken directly from Edison's latest phonograph, and which we therefore know to contain somewhere, if we could but see them, all the elements of that vowel, is generally to the unaided eye a mere enigma. We can carry the visual interpretation a little further by accurate measurement and calculation: this is done by Fourier's theorem.

The two kinds of waves already shown were easy examples which could be roughly analysed by the eye: the one consisted of a fundamental crossed by another tone 9 times as fast; the other of a fundamental crossed by two tones, one 9 times and the other 8 times as fast. But Fourier showed that any periodic wave, however eccentric in shape, could be analysed into a fundamental of the same period, *plus* a series of tones of varying strength vibrating 2, 3, 4, 5, 6, &c., times faster than this fundamental; and he showed how the relative amplitude or swing of each of these elements could be determined. Wherever the analysis of phonograms is hereinafter mentioned it is this Fourierian analysis which is meant. Its result is often to show the appreciable presence of elements of which the unaided eye had no suspicion whatever.

But it is one thing to get a Fourierian analysis of a vowel, and quite another to be able to connect the several parts of this analysis with the several parts of our sense-perception,—its musical pitch, its quality as this, that, or the other vowel, its individual timbre. The musical pitch alone is always clear, because it always divides the phonogram into visible periods. The relative unrecognisability of the vowel vibrations arises very largely from a fact which I had already noticed in my early work on the whispered vowels, before analysed phonograms were accessible, namely, that when a vowel has two or more resonances the relative strength of the resonances is unimportant. "It only reaches prime importance when the one resonance is so strong as to obliterate the perception of the other, or when either of them is so weak that it fails to produce any impression at all on the sensorium."¹

¹ *Phonetische Studien*, vol. iv. p. 41.

This was deduced from actual experiment and observation of resonances, but the same thing is often proved in listening to the phonograph. A phonogram which is most imperfect to the unaided ear often becomes delightfully clear in the hearing tubes. Why? The hearing tube has not made the weaker elements relatively any stronger, but it has prevented them being lost to the sensorium altogether, as they were before. Even these observations, however, scarcely prepare us for the enormous differences which we find in phonograms. Sometimes one resonance comes out in overwhelming strength, sometimes another: even where there are only two resonances the result is that their phonogram, mixed with glottal elements, has a variety of form which to the eye is simply bewildering; and even after a Fourierian analysis it would be a bold thing, as yet, to predict the sound of any vocalic phonogram from a mere inspection of the amplitudes of its elements.

For these elements, after all, are not the pure resonances themselves: they are mainly the partials of the sung note, brought out and magnified by the effects of the resonance: and we can do little more than guess what the unbiassed resonances really would be, by noting what partials they tend to magnify. Sometimes it happens, especially when the resonance is deep and the sung note is high, that the resonance does not coincide very closely with any partial of the sung note. Therefore it magnifies nothing, and makes no visible appearance at all in the phonogram: in the Fourierian analysis, too, its small arithmetical value is partitioned between adjacent partials, and cannot by any possibility be separately recognised and estimated. Hence there are many phonograms in which one or more of the resonances, which we otherwise know to be present, can neither be distinguished by the eye nor by analysis from among stronger elements.

The strongest cases of this kind are those where a vowel is sung at a pitch higher than that of one or more of its resonances. In such a case the resonance always seems absent from the phonogram, at any rate to the eye: I do not think a *series* of such waves has ever been analysed, but the arithmetical value of the resonance must in any case be exceedingly small. This is probably the chief reason why all vowels suffer more or less

in quality at very high pitches. I find practically that it is useless to seek traces of a resonance n except in phonograms which are sung at the pitch $\frac{1}{2}n$ or lower. It is useless, for example, to look for resonances under 300 V.D. except in phonograms sung below 150 V.D.

One very remarkable feature of vowel-curves is well illustrated by the second of Pipping's examples above given. The resonance of vowels, so far as it is exhibited in magnified partials of the glottal note, is discontinuous: it takes a fresh start at each pulsation of the glottis. The resonance exhibited in this phonogram executes just about $8\frac{1}{2}$ V.D. to one V.D. of the glottal note. Therefore, if it had been continuous, it would have entered the second wave of glottal note at the half-wave of its own vibration. In technical language its phase would have been precisely reversed: the second half of our figure would have exhibited a pit wherever the first half has a pinnacle, and a pinnacle wherever it has a pit. But it does not: the vibrations which crossed the first wave die with it, and a fresh beginning is made in the same place as before. This is a very remarkable property: it is universal in phonograms: it doubtless affords to the ear an important criterion for separating resonantal from strictly glottal vibrations, *i.e.*, in enabling it to make separate cognition of vowel quality and musical tone. It proves, also, that in the air of the stoma resonance must subside very rapidly. This is doubtless due to the inelastic softness of its walls.

One very important feature of phonograms remains to be noticed. Every phonogram comes to us through the medium of some vibrator. The pains of the inventors have been successful in removing from most of the phonograms recently published the suspicion of containing elements belonging really to the vibrator itself. The vibrators used have always been carefully devised so as not to vibrate in any rhythm proper only to themselves, but simply to report faithfully vibrations received from without. Yet no vibrator can do this with absolute faithfulness. Each has its own preferences and limitations. It has especially what may be called its 'field of view.' Every sound which is well within a certain range is fully recorded: near the boundaries of that range, whether upper or lower, it is recorded more feebly: above or below those boundaries, not at all. In

the human hearing apparatus this property of our human vibrator, the *tympanum*, is largely provided against by the muscle called *tensor tympani*, which is so placed as to operate strongly in increasing, when necessary, the tension of that organ. The tenser or harder in texture is the vibrator employed, the better it is suited for recording high vibrations, and *vice versa*. Pipping's vibrator was a membranous structure made to represent the tympanum. Hermann has almost always used plates of mineral substances,—latterly the vibrating plates of Edison's phonograph. The result is a remarkable general contrast between their curves, Pipping's field of view being generally lower than Hermann's, so that the glottal tone, the deepest element of the period, generally comes out as a visible rise and fall of the whole curve; but not always. Pipping's phonograms, also, have always rounded pits and pinnacles. This is because his recording pen, or lever, makes a slight friction against the glass, which prevents it recording its extreme swing, either way. Hermann's are much sharper.

The remaining phonograms shown in our diagram are those of a few waves of Hermann's German long *a*, a vowel resembling the English *a* in *father*, in a somewhat Londinised pronunciation. It is here sung at G 99, A 110, B 124, and *c* 132 V.D. respectively, the ordinary talking pitches of a male voice. Their sizes are magnified about three times.¹

These are typical Edisonian phonograms, and they prove beyond dispute that the vibrators of the phonograph are, strictly speaking, nearly, if not quite, deaf to the ordinary speaking pitches of a male voice. For it is seen at a glance that in these curves there is no perceptible fundamental wave. There are well-marked periods, and these periods are precisely those of the glottal note; but the general rise and fall, which would indicate in each period the presence of the fundamental glottal tone, is, so far as the eye can judge, totally wanting. Yet these identical phonograms will reproduce to the auditory sense strong notes of G, A, B, and *c*. How is this? The received theory of hearing, as propounded by Helmholtz, and elaborated by V. Hensen, says that the ear, by means of the *membrana basilaris*, analyses every musical tone into its

¹ *Pflügers Archiv*, vol. xlvii. p. 347.

Fourierian elements or partials. But if the above-depicted curves are so analysed, the fundamental element practically vanishes. Why, then, is it not silent in the reproduction of the phonogram? Hermann says that our theory of hearing is incomplete, and that the ear must possess somewhere the power of recognising *everything which is periodic* in a sound-impression as tone, of the given period or pitch.

To follow out this controversy would be foreign to the present purpose, but another point disputed between Hermann and Pipping is very pertinent here. What is the true meaning of the little cross-vibrations? What are they? Pipping says they are all partials or combinations of partials of the glottal note. So does Hensen. Analyse them, they say, into partials, and there is nothing else left: the analysis is exhaustive. True, replies Hermann, but that result was a foregone conclusion when you began to analyse by that method. Look at these little waves carefully, measure them accurately, and you will find that they are never, except by accident, exact partials of the glottal note. They are quite independent vibrations, having nothing to do with the glottal note at all, except that they take a fresh start at each glottal period.

It will be gathered from the preceding exposition that I do not entirely subscribe to either of these theories. There is much truth in both: the whole truth, I fear, in neither. A resonance is not so much a sound as a possibility of sound, which only comes into actual existence in proportion as it receives stimulation. The vowel resonances always receive stimulation enough from the glottal percussion and friction to make them just sensible to the ear; but it is often the lot of one, and sometimes of more than one, of them to coincide pretty nearly with some partial of the glottal note, and then that partial is greatly magnified.

Closely adjacent partials often profit also by this influence, while remoter partials are damped. These prominent cross-vibrations therefore are, in the main, made up of magnified discontinuous partials of the glottal note, but they contain an independent element also which persists with the articulation under every change of note.

It is surprising to find that the known resonances of a given

vowel may often be quite invisible in good phonograms of it, and may remain still undiscoverable when these phonograms are analysed. How is it, then, that these phonograms can strongly reproduce the vowel? In the first place, the Fourierian analysis ignores all inharmonic elements: it, in effect, partitions them among the harmonics or partials. The exhaustiveness of a Fourierian analysis, therefore, proves little here beyond the correctness of the calculation: a sensible degree of independent resonance may exist all the time, and yet may not appear in any recognisable shape in the analysis. In the second place, it may be noted that vibrations which in themselves are exceedingly weak, such as those which determine the timbre of voices and of musical instruments, are often quite clearly heard as qualifications of a strong substantive sound. Now the substantive sound in a sung or spoken vowel is the musical note, and the vowel only ranks as a qualifying element. Under these circumstances it may easily have an audibility far beyond its own inherent force. In the third place, Hermann's above-noted observations show that under certain circumstances loud tone may proceed from elements which are almost, if not quite, undiscoverable in the analysis of the phonogram. In the fourth place, a Fourierian analysis never represents exactly what takes place in the creation of a phonogram. It exhibits with perfect truth a series of partials of given amplitude and given phase, which, if all impressed simultaneously upon a given particle, would cause it to describe exactly the vibration depicted in the original complex curve. But such an analysis fails precisely in that particular which is the distinguishing mark of these cross-vibrations: it assumes that the amplitude of each partial will be constant throughout the whole of each glottal period, which is just what never can happen with these brief intermittent resonances, besides being flatly contradicted by the visible features of the phonograms.

Are we then to neglect the evidence of Fourierian analyses? Not at all; but let us use them for what they are—approximate analyses of the musical note, in which the vowel resonances only appear incidentally and indirectly, by reason of their power of magnifying those partials with which they may happen to coincide. The two examples of Fourierian analysis which are

given below are taken from an article by J. D. Boeke of Alkmaar in *Pflügers Archiv*, vol. l. p. 297. They are analyses of curves taken directly from the record made on an ordinary Edison cylinder, by Dutch long *aa*, spoken at the pitches named. The vowel resembles the *a* in the English word *man*, as spoken by educated Northern Englishmen, but prolonged. The analysis is carried to twelve partials.

| Pitch of Wave. | Number and Magnitude of each Partial. | | | | | | | | | | | |
|----------------|---------------------------------------|------|------|------|------|------|------|------|------|------|------|------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 175 V.D., . | 1 | 1·31 | 1·30 | 4·19 | 8·09 | 3·73 | 4·41 | 4·50 | 0·30 | 1·74 | 0·82 | 1·21 |
| 184 „ . | 1 | 0·81 | 0·73 | 0·77 | 2·01 | 0·71 | 1·45 | 0·58 | 0·61 | 0·06 | 0·43 | 0·21 |

It will be observed, on scanning these two series of magnitudes, that each of them rises to a temporary maximum at various points. The most marked maximum is on the 5th partial in both cases—875 and 920 V.D. respectively. Next in point of distinctness is that maximum which reposes on the 7th and 8th partials of the first curve, and on the 7th of the second,—1312 and 1288 V.D. respectively. There is a third maximum on the 2nd partial of the first curve—350 V.D.: this resonance comes out very strongly in some other curves of the same vowel. Two less decisive maxima are also to be discerned, the one on the 10th partial of the first curve and the 9th of the second—1750 and 1656 V.D. respectively; and the other on the 12th of the first and the 11th of the second—2100 and 2024 V.D. One of these maxima recurs in other phonograms.

But these are only rough-and-ready estimates. Hermann, in calculating resonances of this kind, adopted what he called a centre-of-gravity (*Schwerpunkt*) calculation,—*e.g.*, to ascertain the first-named resonance of the first curve given above, he would probably take into account not only the 5th partial, but also the 4th and 6th, and proceed as follows:—

$$N = 175 \times \frac{(4 \times 4.19) + (5 \times 8.09) + (6 \times 3.73)}{(4.19 + 8.09 + 3.73)}$$

thus multiplying the fundamental pitch by the 'mean partial' of the reinforcement to find the pitch number of the resonance. Pipping here objects, saying, in effect, that this calculation assumes the 4th, 5th, and 6th partials to be equidistant from each other, although in a musical point of view they are not,—the distance between a 4th and a 5th partial being 4 semitones, whilst that between a 5th and a 6th is but 3: their musical distances being not proportional to (5-4) and (6-5), but to (log 5-log 4) and (log 6-log 5) respectively.

Following this view, I have used, in estimating resonances from Fourierian data, the following formula:—

$$\log p = \frac{a' \log p' + a'' \log p'' + a''' \log p''' + \text{etc.}}{a' + a'' + a''' + \text{etc.}}$$

where p' , p'' , p''' are successive integers, the numbers of the partials involved, and a' , a'' , a''' are their amplitudes: p is then the 'mean partial,' and when multiplied by the pitch number it gives the estimated resonance. But the difference between this and Hermann's calculation is only considerable when the fundamental or some other of the lowest partials is involved. In looking for maxima of this kind, let it be remembered that, unbiassed by resonance or by vibrators, the partials have a general tendency to decline in amplitude as they recede further from the fundamental. The annexed table shows the results which have followed from examining Hermann's, Pipping's, Boeke's, and other phonograms in the manner just sketched.

The arrangement of that table is based upon a further investigation, the detailed description of which would require another article. Following up a hint of Helmholtz¹ respecting the *i* vowel, I pointed out in my Cardiff paper (1891), and in my articles in the *Phonetische Studien*, 1890-2, the probability that every cardinal vowel derives one chief resonance from the anterior or oral part of its articulation, and another from the posterior or pharyngeal part. The resonances of column β are those which are found to be due to the anterior tube or cavity of the articulation. This assignment is fairly certain, because it can be confirmed by direct observation in whisper, by the

¹ *Sens. of Tone*, p. 107.

behaviour of imitative cavities, and by careful measurement and calculation. The column α contains the resonances assigned to the posterior cavity. This assignment is less certain than that of column β , because none of these resonances lend themselves to direct observation in whisper. But the only ones which are not fairly confirmed by measurement and calculation are those of u ; and here the posterior articulation itself is still somewhat obscure. Columns γ , δ , and ϵ contain resonances respectively lower than, intermediate to, and higher than α and β . The γ resonances have so far been found in all α vowels, and in those only. They seem possibly due to the trachea (see previous article on *The Genesis of Vowels*, p. 233). The δ resonances are confined to the tube-vowels i and e . They do not always appear, and are possibly due to an intradental cavity which forms itself in front of the articulation when the tongue is much arched. The ϵ resonances are confined to the middle or 'expansible' series of vowels. It is difficult to see any organic cause for their production. They seem to be related to the β resonances very nearly in the ratio of 3 to 2, but whether this relationship is necessary or in any sense causal does not yet appear.

The resonances of wide-mouthed cavities are much less sharply defined than those of narrow-mouthed cavities. Hence the resonances of the expansible vowels often have effects spreading over several adjacent partials of the sung note. Such resonances are indicated in the table by the letter c (= circa).

POST-MORTEM ARTIFICIALLY CONTRACTED INDIAN
HEADS. By HERBERT PAGE, M.D., D.P.H., Redditch.

SOME time ago two specimens of artificially contracted Indian heads, received by a townsman from a relative long resident in Gualaceo, Ecuador, were submitted for my inspection. Being interested in the matter, I carefully examined them, and looked up the subject from scattered authoritative sources. I submit the annexed summary and the details of my examination of the two specimens.

Artificially contracted human heads have been known in Europe for, I believe, about forty-five years. The specimens belong, almost without exception, as far as I can ascertain, to the Indian tribes of South America. Specimens are not now rare, but can be met with in several of our own and various Continental museums. The more warlike and independent tribes of Indians seem to be the chief contributors of specimens. Perhaps the most frequent source are the Javaros Indians, living on the east side of the Andes; other contributory tribes of the West Amazon are the Mundurucus, the Makas, the Dyaks, the Canelos, and the Pinbuc Indians. The names 'Momea' and 'Chancha' are, I learn, commonly given to the specimens by the natives. The object of the preparation of the heads is to preserve them as trophies of valour, but occasionally they become idols or oracles. Wood, in his *Natural History of Man*, vol. ii. p. 575, says, "the Mundurucus perpetuate the memory of valiant deeds by preserving a trophy of the slain enemy. Indeed, this is the only way in which it is possible to preserve the accounts of their valour; and the Mundurucus follow in this respect the example of the Dyaks by cutting off and preserving the head of the dead man." Usually these preserved heads are considerably contracted, but one authority states,—“The Mundurucus preserve the heads of their enemies, but leave them the natural size.”

The following is a list of known specimens I have been enabled to compile:—

1853. London. Specimen of Indian Javaros exhibited, only
1 in. high.

- 1860.* „ Specimen found with tools in ancient grave at Pisciken.
1862. „ Specimen called an 'idol's' head.
- 1874 May. Two exhibited at Anthropological Institute, London. One reduced (circumferentially) to 11 in., the other 9½ in.
1882. London. Specimen exhibited, called 'head of Incas.'

The British Museum possesses 4† or more specimens; Brighton Museum, 1; Manchester (Owens College), 1 (very perfect); Cambridge University, 3; Antiquarian Museum, Edinburgh, 1‡; Edinburgh University Anatomical Museum, 1; Dublin University, 1; Berlin University (Ethnolog. Department), 3,—the 1st, received from German consul at Panama in 1868, described at the time as the 'skull of an Aztec': this error arose by the arrival, also from Panama, by the same ship of a company of Aztecs or Pigmies, on tour in Europe. It turned out to be the head of a Javaros Indian, and was stated to be "the first specimen seen in Europe." Vienna Public Museum possesses 3 specimens, and there are 3 more in the Pathological Museum. This makes 27 known specimens. Further, I am informed trustworthily that a good number of specimens are to be met with in Italy,—Professor Giglioli being an authority on the subject.

Mode of preparation.—This, as related by various authorities, differs slightly. It is said to have been described by an American traveller "O.," who travelled in Ecuador and published his *Travels along the Negro River* in 1880–81, but I am unable to trace the book. Sir John Lubbock, in "Notes on the Macas Indians," *Journal Anthropol. Inst.*, 1874, says "the process is very simple. The heads are boiled for some time in an infusion of herbs, the bones are then removed through the neck, heated stones

* Communication to Ethnological Society, London, 1860, by Mr M. Bollaert, on the Idol Human Head of the Jivaro Indians.

† Guide to British Museum—American Sec., under Brazil :—"Cases 86–88 have in the Ethnographical Gallery two preserved heads from Mundurucus on the Amazon, two shrunken heads, prepared by Javaros Indians."

‡ The specimen in the Antiquarian Museum, together with one in the possession of Dr Alfred Pullar, were described by Professor Duns in *Proc. Roy. Soc. Edinburgh*, vol. xiii. p. 621, 1886. A specimen is also in the Pitt-Rivers Collection in the Oxford Museum, and one was shewn by Dr Stolpe to the Medical Society in Stockholm.—EDITOR.

are then put into the hollow, and they are, when cool, replaced by others. The head dries and contracts. A string is then run through the head, by which it is suspended in the hut." Wood, in his *Natural History of Man*, says, the Mundurucus and Dyaks "cut off the head with his bamboo knife, removes the brain, soaks the whole head in a bitter vegetable oil called 'anderoba,' and dries it over a fire or in the sun. When it is quite dry, he puts false eyes into the empty orbits; combs, parts, and plaits the hair, and decorates it with brilliant feathers; and lastly, passes a string through the tongue, by means of which it can be suspended." Bollaert says, "After a war, the heads of the victims are cut off, the skull and its contents removed, and a heated stone (it is said) is introduced into the hollow of the skin, desiccation goes on, and it is reduced to about one-fourth, retaining some appearance of the features." "A double string is attached to the top of the head, so that it may be worn round the neck. The lips are sewn together, and a number of strings hang from them, the use of which is not apparent."

Simson (*Journal Anthropol. Inst.*, 1880) says, "To produce these ghastly objects, the skin is cut round the neck, and the entire covering of the skull removed in one piece; they are gradually dried by means of hot stones placed inside; the head shrinks to the required size." He says also, "the Pinbuc Indians have a very perfect and finished method of scalping, by which the victim's head is reduced in size to that of a moderately large orange, maintaining tolerably well all the features; . . . the nose, of course, acquires too much prominence."

The attached strings.—These, it will be observed, are for suspension "in the hut" (Lubbock); "in the malocca or council-house" (Wood); "round the neck" (Bollaert). "The use of the lip strings is not apparent" (Bollaert).

Customs or Ceremonies connected with the heads.—Sir John Lubbock says, "the head is abused by the owner, then answered by a priest speaking for the head, after which the mouth is sewn up to prevent any chance of reply." Wood says, "when the chief gives orders for a feast, the proud owner of the head arrays himself in his most magnificent suit of feathers, fetches his prize from the malocca, fixes it upon the point of his spear, and parades himself before his companions in all the glory of an

acknowledged brave." Bollaert says, "a feast ensues, when the victor abuses the head roundly, to which the head is made to reply in similar terms, the Indian priest being the spokesman for the head or chaucha (an Indian name for a sow), and he concludes his part thus: 'Coward! when I was in life thou didst not dare to insult me thus; thou didst tremble at the sound of my name. Coward! some brother of mine will avenge me.' The victor at this raises his lance, strikes and wounds the face of his enemy, after which he sews the mouth up, dooming the idol to perpetual silence excepting as an oracle, questions being put to it when the inquirer is under the spell of a narcotic."

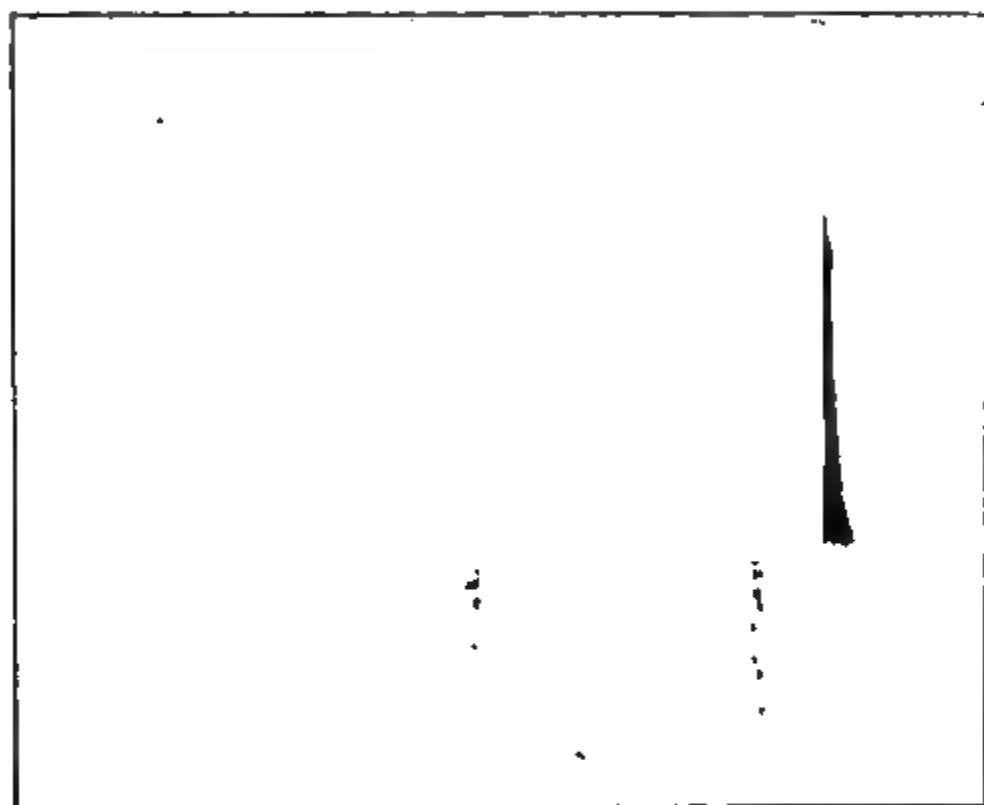
Financial value of these heads.—As far as I can ascertain, this ranges from £20 to £28 for very good specimens. At New York it is said one can, through the proper channels, "get as many as you like at £25 each." The owner of the heads I examined informed me that the relative from whom he received them wrote that he sent his son into the interior to the Indian tribe to fetch them; also, that some time previously he sold a similar specimen for 28 dollars (£5, 12s.), which was reported to have been subsequently resold by the purchaser to a museum for £70, and that another specimen which had been obtained by a Frenchman was purchased for the Berlin Museum for 1700 francs (£68).

Experiment.—I learn from a distinguished anatomical authority in England, that if a dried, preserved human head be softened in boiling water, and by means of an incision along the occiput the soft parts be peeled from the bone, it will shrink in exactly the same manner as these preserved, contracted Indian heads.

The specimens examined by the author were:—

Two specimens received at Redditch—sex and age.—Two small decapitated heads, both apparently male: vertical height of larger one 9 cm.; of smaller, 8 cm. The larger is by far the more perfect, possibly about 25–30 years of age; the features are remarkably well preserved, the expression calm and not unpleasing. The other head is considerably smaller; and though equally well preserved, the features are not so well marked, the expression is less calm and pleasing, the left ala of nose is wanting. It is apparently slightly younger and of a different racial type.

General observation—external examination.—The heads are perfectly dry, of wooden hardness, and jet black in colour, matt surface. The rows of papillæ of the skin are distinctly visible, particularly in the smaller head; no artificial deformation is present in either specimen. The heads dolichocephalic, and the features are sharp, the zygomatic arches well marked, the jaws slightly prognathous, more particularly those of the smaller specimen.



Point of decapitation.—The point of decapitation in the smaller head is 3 cm. below the lobe of the ears; the aperture of the neck is ovoid; the integument is reflected over an ellipse (3.5 × 3 cm.) of wood, to which it is lashed by 37 continuous overcast stitches of twisted hempen cord. The point of decapitation in the larger head is 2 cm. below the lobe of ears; the ellipse is 2.5 × 2 cm. There are no attachments.

Odour.—The odour of the heads is distinctly aromatic and bituminous, specially marked in the smaller head. The hair of the smaller head feels slightly unctuous, and has the aromatic odour. In the hair of the larger head the unctuousness is absent, and the odour very faint.

Nose.—The extremity of the nose in the smaller head is everted upward; it is 1.5 cm. wide, and projects 2 cm. from the

root of the organ. The nostrils are very slightly elliptical; the

columnna of the septum is broad. The nose in the larger

specimen is straight, otherwise similar to that of the smaller. The left ala is wanting; and several patches of loss of the bituminous substance are noticeable about the nose.

Lips.—The lips of the larger head are of the 'Negro' type, prominent, and 8 cm. thick; they are pierced by 3 wooden pegs 5 cm. long; the edges of the apertures are rounded like that present in the ear lobes. The lips of the smaller head are less everted and prominent, and through and from them depend 42 brownish-coloured twisted cotton cords, arranged in 4 skeins, each 23 cm. long.

Eyes.—The eyelids only are present; the palpebral apertures in the smaller head are half open, are small, and horizontal in direction. The superciliary ridges are prominent and the eyebrows thick; the hair is 5 mm. long, directed towards the outer angle of the eye. The eyelids in the larger head are closed, the superciliary ridges not marked, and their hair unnoticeable.

Ears.—The ears in both specimens are perfectly preserved, are markedly developed, and have large lobes. In both specimens each lobe is pierced, and carries a short wooden peg, directed backwards.

Hair.—The hair of the larger head is very abundant, jet black, smooth and wiry, and is 53 cm. long. That of the smaller head is also abundant, a very deep chestnut-brown colour, and extremely silken to the touch. In both cases the hair is firmly attached to the scalp.

Race.—From these considerations, the racial type of the heads indicate the 'American'; at all events, it is not 'Negro.'

Suspensory Cords.—Through the vertex of each head a double two-braided cord of hemp is passed, for the purpose of suspension. The cord attached to the larger head is 35 cm. long; it is tied to a loose cross-piece of wood inside the head, beyond which, through the neck aperture, one portion of the cord projects 28 cm. The total length of this cord is about 100 cm. In the case of the smaller head, the suspensory cord is 28 cm. long, and ends inside the head. Its length is about 60 cm.

Head.—At the back of the neck in both cases an incision has been made from the divided neck-tissues to the position of the superior curved line of the occipital bone, and subsequently closed by continuous stitches. In the case of the smaller head

there are small areas of soft tissue, corresponding to the posterior superior angle of both parietal bones.

Internal examination.—Owing to the smallness of the heads, of the apertures of the neck, and hardness of the tissues, digital examination is difficult; and owing to the dark staining of the tissues, examination of the interior of the heads by light is unsatisfactory. As far as can be ascertained, every particle of the bones of the skull has been removed.

Microscopic and Chemical examination.—A fragment taken from the neck (transverse section) showed ($\times 450$) normal connective-tissue and fat cells, with glandular tissue and a hair bulb. The yellowish stain from the preservative materials extended about half-way through the sections of the tissues examined. Chemical examination showed traces of Ca, heavy traces of NH_3 , much Cl. Na. and P. Considerable traces of tannin. The tissues readily softened in boiling water; they also yielded a brownish-yellow solution to alcohol and ether. They were readily inflammable, giving off much smoke and an aromatic odour. Microscopic examination of some fragments from the interior of the heads showed resinous particles, no crystals of bases, but a few clusters of mucor mucedo. The hairs from the scalps proved to be round and smooth; detached cylinders of medullary substance were visible in the hairs from the larger head. The suspensory cords proved to be hemp; those of the lips of the smaller head, cotton.

Leading Anthropological Data.

(For comparative purposes a male European skull was used.)

Weight: Skull 640 gms. Large Head 355 gms. Small Head 55 gms.

| | | | | |
|--------------------------------|---|-------------|-----------|----------------|
| Cranial capacity in No. 6 shot | { | Skull . . . | 9952 gms. | vol. 1470 c.c. |
| | | Large Head | 1050 „ | „ 144 „ |
| | | Small Head | 505 „ | „ 72 „ |
| Cranial capacity in fine sand | { | Skull . . . | 2355 gms. | vol. 1082 c.c. |
| | | Large Head | 255 „ | „ 162 „ |
| | | Small Head | 125 „ | „ 78 „ |

Cephalic Index: Skull . 78.8. Large Head 8.2. Small Head 7.9.
 Facial Angle „ 80.0° „ 46.0° „ 40.0°
 „ „ of Negro 69.0° Gorilla 31.8° Dog 25.0°

Remarks.—The heads examined were probably prepared by Javaros Indians, or one of their neighbouring tribes. It does not appear, and I am told, that these tribes do not preserve

or mummify any other part of the body. A distinguishing feature in the larger head examined is the presence of wooden pegs in the lips and ears. This custom does not appear to have been noticed in any of the notes I have been able to refer to, nor is it noted in any of the specimens of which I have collected notes. The presence of lip pegs in the larger head, and of lip strings in the smaller specimen deserve notice. Closure of the lips, by either pegs or strings, may be only alternative or distinctive tribal customs, to indicate absence of organic function, except when the head is consulted as an oracle. Similarly, if the ear-attachments indicate abolition of the function of that organ, we should have expected cords to have been used (as in the lips) in the case of the smaller head. Possibly pegs or cords may be used indifferently in the same head for symbolic purposes. On the other hand, these ear-attachments may be simply ornaments. Notice cannot fail to be taken of the long, black, coarse, wiry hair of the larger head, contrasted with the nut-brown, fine, silky hair of the smaller head. Another differentiation of the heads is the presence of sutures in the divided tissues of the neck of the larger head; their absence in the smaller specimen. There were no artificial eyes, no trace of tattooing or coloration, of feathers, or other decorations, on either head. The usual amount of contraction of these preserved heads is estimated by Ballaert as "above one-fourth." The measurements of the two specimens submitted to me indicate a shrinkage of not less than one-tenth, computed both for size and weight. The extreme limits would appear from my notes to be from natural size to 2.5 cm. (1 in.). The relative proportion of Na. and Cl. found in the fragments of the neck tissue I examined chemically would suggest that common salt played an important part in their preparation, or that the water in which they were boiled (if so treated) was rich in the salts of these elements, whilst the tannin and phosphorus were probably contributed by the vegetable used as the astringent or tanning agent. From the colour, aromatic odour, hardness, and inflammability of the tissues of the smaller head, it is suggested that bitumen or other resinous substances, by the aid of heat, were used in the process employed.

Appended are the details of the results of the examination of these shrunken Indian heads from South America.

THE GLANDS OF THE CILIARY BODY. By LESLIE
BUCHANAN, M.B. Glas., *Pathologist, Glasgow Eye Infir-*
mary. (PLATE X.)

IN the *Archives D'Ophthalmologie*, 1890-1891, there appeared a series of articles by Dr Nicati of Marseilles, in which the results of a long series of experiments and observations regarding the origin of the aqueous fluid in some of the lower animals were made known.

In summing up his results, Dr Nicati states that the aqueous fluid is secreted by the epithelium of the pars retinæ ciliaris together with the vascular and lymphatic channels surrounding this part, which, taken together, he terms the uveal gland.

At the same time, namely early in 1891, Mr Treacher Collins, in an article published in the *Transactions of the Ophthalmological Society*, took a step in advance, in showing for the first time the existence of glands by means of which the secretion of the fluid might be accomplished in the human and other subjects.

By the use of bleaching agents, Mr Collins was enabled to show that certain outgrowths from the pigment epithelium of the ciliary region were true glandular structures; and he stated that he considered that these might possibly take part in the secretion of the aqueous fluid.

Since Mr Collins' paper was published, but little evidence has been brought forward corroborating his observations, whilst many criticisms, more or less adverse, have been made; hence it has been thought wise to publish the results of some recent work which agrees in most respects with that of Mr Collins, and to illustrate, so far as possible, by means of photomicrograms sections of the glandular structures under various conditions. Before doing so, however, it may be well to recall a few points in connection with the aqueous fluid, and with the anatomy of the ciliary body.

The aqueous fluid is a limpid fluid, containing but a small percentage of albumen and but a trace of salts, which fills the

anterior and posterior chambers, permeates the vitreous body, and acts, most probably, as a nutrient medium for both this and the crystalline lens. It is the aqueous fluid which serves to keep in health the tension of the eyeball at a normal standard, by means of a well regulated adjustment acting on the local vascular system.

From pathological and experimental results, it is found that the fluid is secreted behind the iris, that part of its current passes backwards through the vitreous body, whilst the remainder passes forwards to and through the pupil into the anterior chamber, whence it escapes by the spaces of Fontana into the canal of Schlemm.

By the fact that when the iris is either absent from birth, or is removed *in toto* by accident or by operation, the tension of the eyeball is maintained at the normal standard, it is rendered most probable that the iris itself is not even a principal source of aqueous fluid. When the ciliary body is excised, as has been done, the ocular tension falls, and the secretion of the aqueous fluid ceases, showing that this part of the eye, at all events, is intimately concerned with the elaboration of the fluid.

Referring now to the anatomy of the ciliary body, it is found that the ciliary region, which extends from the base of the iris to the ora serrata, is divided into an anterior thickened and folded portion and a posterior smooth portion, termed respectively the "*pars plicata*" and the "*pars non-plicata*."

Two sets of elements enter into the formation of the ciliary body, namely, one derived from the choroid, and consisting of the muscular and vascular systems, and the other, the *pars ciliaris retinae*, derived from the retina, which lines, as it were, the former set internally, and is separated from it by a hyaline lamina.

With this set of retinal elements we are specially concerned, it being the secreting area, as it were, of the aqueous fluid.

It is composed of an internal layer of elongated columnar epithelial cells, which is a continuation of the main body of the retina forwards from the ora serrata, and an external layer of cubical, deeply pigmented epithelial cells, which is continuous with the layer of hexagonal cells of the retina.

It is from this pigmented layer of cells that little processes

or outgrowths arise, which are easily seen in most radial sections of the ciliary body, lying internal to and abutting upon the hyaline lamina, and which Mr Treacher Collins was first to describe as true glandular structures.

These processes vary in size, are mostly single, sometimes branched, and are always deeply pigmented. They are generally pear- or club-shaped, and vary in number in the two parts of the ciliary body.

In the pars plicata the processes are only found at the posterior portion, but they are here most constantly seen and are of largest size, measuring from $\cdot 15$ to $\cdot 10$ mm. long, and from $\cdot 10$ to $\cdot 05$ mm. broad, and averaging five in a section.

In the pars non-plicata the processes are found to be smaller, measuring only $\cdot 06$ to $\cdot 04$ mm. long and $\cdot 04$ to $\cdot 03$ broad, they are in much greater numbers than elsewhere, averaging 25 per section, but often found to the number of over 100 per section, and are not of constant occurrence.

In the pars non-plicata there is sometimes a thickened portion, where a group of glands closely packed together may be found. It appears to be the case that the processes are of almost uniform occurrence round the whole ciliary region.

By taking an average of twenty-five processes per section, and estimating from the thickness of the sections the diameter of the glands and the circumference of the ciliary body, it may be computed that the total number in an eye may be 10,000.

Referring to Plate X., fig. 1 is a drawing, from a photograph, to represent the ciliary body; and in its posterior surface, near the posterior limit of the pars plicata, there are seen three such processes as above referred to. These processes are pear-shaped in section, are smaller than the sulci, from which they must be distinguished, and further, that one of them has a lumen, and an opening upon the surface of the ciliary body, and one only.

The glands must be carefully distinguished from transverse sections of sulci; and it may be seen that sulci, cut across, must almost all have a surface opening, whilst, on account of the narrow nature of the lumen, it is extremely rare to find a gland having such an opening.

Fig. 2 shows the group of glands seen in fig. 1 as three small processes magnified highly; and here, on account of the lightness

of the pigment in the original, the glandular nature is easily seen; a basement membrane bounding a cavity lined by large cells of epithelial nature, and having an opening upon the surface in one instance only.

Fig. 3 shows the position and appearance of the processes or glands in the pars non-plicata, with the relations of the structures to the epithelium above, and the fibrous tissue and vascular system underneath.

Fig. 4 represents the same portion of the ciliary body deprived by bleaching, of its natural pigment, and allowing the relationship to be more easily seen.

Fig. 5 shows the appearances seen on making tangential sections of the pars non-plicata, and consequently getting transverse sections of the glands.

Fig. 6 is drawn from the same section after bleaching, and shows very clearly the transverse section of the tube of a gland, namely, a ring of epithelial cells, with a central lumen.

In these sections one or two capillary blood-vessels are seen, lying near the glandular structures.

From these appearances seen in the various figures, it is obvious that the so-called processes are truly glandular structures, and are not either sulci or solid pegs of epithelial cells, as has been said of them by some, for the undoubted presence of a lumen in certain instances renders this latter view almost entirely impossible.

For further evidence, sections of the ciliary body in various diseases have been examined. Figs. 7 and 8 represent a portion of the pars plicata in a condition of acute inflammation (cyclitis), and it is seen that the glands are elongated, distorted and dilated to a marked extent, and probably are secreting more fluid and a more highly albuminous fluid than normal, whereas in fig. 9 the state of cicatricial formation destroying the epithelium, has caused almost entire destruction of the gland and its epithelium, and also its functional activity. Several diseases of the eye have been shown to be in connection with these structures; but in general only one circumstance must be mentioned, namely, that in cases of acute inflammation the tension of the eyeball is increased, whilst in cases of chronic inflammation of the uveal tract or ciliary body the tension of the eyeball is lowered per-

manently if the ciliary body be atrophied, but temporarily if only blocked up.

Regarding the function of these glandular structures, it may be said that nothing definite is known; but on taking into account their position, their glandular appearance, and intimate connection with the vascular system, and finally the fact that, so far as is known, only one fluid is secreted in the eyeball, it seems very highly probable that these structures are in some way connected with the elaboration of it. Further, if it be asked, Are these structures present in sufficient numbers, presuming that they do secrete aqueous fluid, to secrete it so quickly as to satisfy the demands of the occasion? it may surely be answered in the affirmative. For, even though the aqueous fluid be supplied in sufficient quantity to refill the anterior chamber, after evacuation, in five minutes, it is not necessarily new secretion, but fluid drained forward from the vitreous, which replaces that drawn off; and lastly, the tension being lowered, the secretion will certainly take place more quickly.

As the methods of preparing the specimens have been somewhat different from those usually employed, a few words may be permissible regarding them.

The eyeballs were hardened in a weak solution of chromic and acetic acids, four days sufficing to complete the process. Sections were cut in gum, and stained in Kleinenberg's hæmatoxylin, and after staining, cleared with acetic acid and mounted in glycerine.

Sections to be bleached were immersed in a solution of euchlorine for twelve to twenty-four hours, washed for six hours in water, and stained as above.

The euchlorine solution was prepared as follows:—One dram of chlorate of potash was put in a stoppered bottle, and three drams of strong muriatic acid poured upon it, and the whole well shaken. Then, after five minutes or so, three ounces of water were poured into the bottle, and the whole again shaken. The result is a solution of a greenish-yellow gas in water, and consists of a mixture of chloric and chlorous acids and free chlorine.

Notwithstanding the fact that the sections have been immersed for such a prolonged period in such a highly acid solution, no damage seems to have resulted.

Photography was performed by means of Zeiss apochrom. objs. 35 mm. and 8 mm. 2 and 4 oculars (project.).

I have also to acknowledge here my indebtedness to Dr Campbell M'Clure, of Glasgow, who has kindly drawn the diagrams in the Plate from my photo-micrograms.

EXPLANATION OF PLATE X.

Fig. 1. Radial section of pars plicata of the ciliary body, showing a group of three glands, one of which has an indication of an orifice at the surface. $\times 40$. *a*, glandular structures; *b*, duct and orifice; *c*, blood-vessel; *S*, Sclerotic coat; *M*, ciliary muscle; *E*, epithelial layers.

Fig. 2. Portion of No. 1, including the glands, showing duct and orifice of one, whilst two others have no opening. (Lettering as above.) $\times 350$.

Fig. 3. Radial section of pars non-plicata of ciliary body, showing numerous glandular structures lying in different planes, and causing slight elevation of the epithelium. (Lettering as before.) $\times 100$.

Fig. 4. Part of the same section as No. 3, bleached, showing a blood-vessel lying amongst the glandular structures. (Lettering as above.) $\times 150$.

Fig. 5. Tangential section of pars non-plicata, showing a group of glands, most of which have a distinct central orifice. $\times 350$. (Lettering as above.)

Fig. 6. Part of No. 5, bleached, showing similar structures more distinctly. $\times 350$. (Lettering as above.)

Fig. 7. Part of the ciliary body from a case of acute cyclitis, showing glandular structures elongated and dilated, bleached. $\times 200$. (Lettering as above.)

Fig. 8. Part of fig. 7 more highly magnified, showing clearly the tube of the gland dilated and elongated. $\times 350$.

Fig. 9. Part of the ciliary body in chronic cyclitis, showing atrophy and destruction of the epithelium, and great formation of fibrous tissue. $\times 200$. (Lettering as above.)

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A DESCRIPTIVE ACCOUNT OF THE GENITAL APPARATUS IN THE BOAR AND IN THE PIG. By JOSEPH GRIFFITHS, M.A. (Cantab.), M.D. (Edin.), F.R.C.S. (Eng.), *Assistant to the late Professor of Surgery and Additional Examiner in Surgery in the University of Cambridge, and Surgeon to Addenbrooke's Hospital.* (PLATE XI.)

THE differences between the genital apparatus in a full-grown boar and that in a full-grown pig are so striking as well as instructive that I propose to give a brief descriptive account of them. The only essential difference between a boar and a pig is, that the latter is deprived of its testicles—the chief and dominating sexual glands—during the first weeks of its life: and the differences that exist between the sexual organs of each undoubtedly result from the loss of the influence the testes naturally exert upon the growth of the accessory sexual glands and upon the muscles concerned in the expulsion of the seminal fluid.

It is my intention to give a description only of the sexual organs, as I have elsewhere entered into the manner in which the testes exert an influence upon the growth of the genital apparatus and upon the system generally; and further, I have shown that no other part of the genital apparatus possesses a like influence (see "Observations on the Testes," Hunt. Lect. R.C.S. Eng., *Lancet*, Mar. 1895).

THE GENITAL APPARATUS OF A BOAR.

It would be superfluous to give a description of any part of the genital apparatus of the boar that does not serve for comparison with similar and altered structures in the pig. Therefore, my description will be confined to the accessory sexual glands, namely, the prostate, vesiculæ seminales and Cowper's glands, to the vasa deferentia, to the so-called membranous portion of the urethra (intra-pelvic portion of the genital part of the urethra, according to my own nomenclature), and lastly to the special muscles of the penis.

The Prostate Gland.

The prostate gland is of comparatively small size, and lies on the dorsal surface of the urethra, just where the genital ducts enter, and it is partly under cover of the overlapping vesiculæ seminales. It measures about $1\frac{1}{4}$ inch in length by about $1\frac{1}{2}$ inch in breadth, being a little larger in its transverse diameter; it consists of two lobes which by dissection can be easily separated from one another (see Pl. XI. fig. 2). Each lobe is divided into several lobules about the size of peas, which are separated from one another by thin partitions of fibrous connective tissue. The fibrous investment of the whole gland is insignificant, and there is nothing like the definite capsule seen in the human subject. The ducts, of which there are several from each lobe, open into the urethra in a part corresponding to the *sinus prostaticus* of man.

The lobules into which this gland is divided are, as seen under the microscope, subdivided into smaller lobules; and these smaller lobules are surrounded by a thick layer of fibrous tissue in which there are many well-formed unstriped muscular fibres. From the inner surface of this investment, which serves to separate the lobules from one another, the septa proceed, and pass in between the terminations of the gland tubules which are closely packed together. The septa separating the individual tubules are only thick enough to carry capillaries and small blood-vessels, and only in places do they contain unstriped muscular fibres. The termination of the tubules vary much in size, some being small, some large and distended with secretion, and others still of moderate size. In the small tubules there is a single layer of columnar cells lining the wall which is constituted by the thin septum above alluded to; these cells have each a small round nucleus near the attached end, and their protoplasm is finely granular and slightly opaque. In the large tubules the cells are not so regular in their outline and arrangement, being somewhat altered by compression from the contained secretion (see fig. 7).

It is worthy of note that the prostate of the boar differs somewhat from that of man and of the dog in the fact that there is almost an absence of unstriped muscle-fibres in the

inter-tubular connective tissue. They do, however, exist, but not in great abundance, in the larger septa between the lobules.

The Vesiculæ Seminales.

The vesiculæ seminales are of very large size, each lobe measuring 3 inches in length, 3 inches in breadth, and about $1\frac{1}{4}$ inch in their greatest thickness. They lie one on each side of the urethra and neck of the bladder, and enclose the urethra behind but not in front. Behind the urethra they partially embrace the prostate gland and almost obscure it. Indeed, after a hurried examination, I concluded that these vesiculæ constituted the prostate gland, and that the vesiculæ seminales themselves were absent, as in the dog. This, however, is incorrect, and I take this opportunity of pointing out the error I fell into in my account of this specimen in the *British Medical Journal*, vol. 11, 1895, p. 1338.

Each lobe is made up of several large lobules which in their turn are composed of numerous smaller ones. Both the large and the small lobules are connected together by loose fibrous connective tissue, and the whole is enveloped in a fairly well marked membrane of similar tissue constituting a capsule. Each lobe has a membranous duct, which is of small size, and which enters the dorsal wall of the urethra along with the termination of the vas deferens, to the outer side of which it lies.

The gland on section is seen to be composed of numberless spaces, filled with a thin, almost watery secretion. Each space, which corresponds to a distended tubule of the gland, is surrounded by a thin wall of fibrous tissue, in which there are many unstripped muscular fibres. On the inner surface of this wall lies a layer of tall, large columnar cells with granular protoplasm.

Cowper's Glands.

Cowper's glands, which in this animal are remarkable for their size, form large three-sided pyramidal, firm masses, one on each side of the dorsal half of the membranous urethra (see Pl. XI. fig. 1). Each measures $4\frac{1}{2}$ inches in length, and at the distal or lower end the thickest parts are $1\frac{1}{4}$ inch in thickness. Each

gland is partly covered by a thick layer of striped muscle on the dorsal surface, the fibres running outwards and backwards taking origin from and ending in the capsule of the gland. From the distal end of each gland a large duct of about $\frac{1}{4}$ of an inch in diameter emerges, and after a course of about 1 inch it pierces the wall of the urethra. The duct, if traced into the gland substance, widens almost immediately into a large channel, from which other ducts pass outwards in various directions. The lumina of the main and secondary ducts are so large, that doubtless they act as reservoirs for the accumulation of the secretion of the gland until it is needed. In the recent state they are filled with a very tenacious, mucoid secretion.

The gland substance is composed of vesicles or saccules, some of which are simple, but most are compound; and their walls are composed of a thin layer of connective tissue, lined by a single layer of tall, well-formed columnar cells, with small round nuclei near their attached ends; the cells contain an intra-protoplasmic network, the spaces of which are occupied by clear protoplasm, as in mucous glands (see Pl. XI. fig. 9). The interior of the vesicle is filled with the same kind of material as that seen in the main duct, namely, a transparent, thick, tenacious, mucoid secretion which swells out like gelatine when placed in water.

These glands, therefore, secrete a thick substance which is collected and probably stored in the main, and, it may be, also in the secondary ducts, and from these it is probably expressed by the striped muscle already referred to and lying on the exterior of the gland.

The Membranous Urethra.

The membranous urethra is long and very large, measuring at least an inch in diameter. Its lumen is large, and the wall is composed chiefly of a thick layer of transverse striped muscle and of a very thick mucous membrane. The striped muscle forms, in transverse section of the urethra, a ring which is thick in front, and which gradually thins on the sides until, in the middle of the dorsal surface, it is represented only by fibrous tissue. In front, it measures 5 mm. in thickness. This is the homologue of the constrictor urethræ of man, and, like that muscle, it begins as a few transverse fibres (the Ext. Sph. of Henle of man) on the

ventral wall, at or near the level of the entrance of the genital ducts into the urethra: soon the muscle extends on each side to the dorsal surface, where, as I have said, it thins out and ends in fibrous tissue. This muscle extends without a break along the membranous portion of the urethra to the triangular ligament, in other words, to the root of the penis. The muscle fibres of which this is composed are large and well developed, being like in every respect the fibres in a natural skeletal muscle (see Pl. XI. fig. 3).

The inner wall is very thick, measuring 4 mm. in a radial direction. It consists of a mucous membrane and a very thick glandular submucous tissue. The mucous membrane is lined by a thin layer of stratified epithelium, and this is like every other of its kind. The submucous glandular layer, which has a distinct representative in man, is very thick, and in it there is a remarkable development of glands. It is divided by thin radial partitions of fibrous connective tissue into several wedge-shaped areas, as seen in transverse sections, with their broad ends outwards. Each piece is composed of areolar connective tissue, supporting numerous and closely packed glandular tubules which are of small size. The tubules, as seen in transverse section, are lined by a single layer of sub-columnar epithelial cells with round nuclei and granular protoplasm: each tubule is surrounded by a single layer of flattened connective-tissue cells which form a sheath or ring around it. All the tubules end in small ducts, which ultimately lead to the terminal ducts which open on the surface of the mucous membranes of the urethra. The lumen of this part of the urethra is large, and it would seem that under natural conditions it is more or less filled with secretion derived in all probability from these urethral glands (see fig. 3).

Special Muscles of the Penis.

These muscles are large and well developed being in appearance and structure like ordinary skeletal muscles.

GENITAL APPARATUS IN A FULL-GROWN PIG.

In a full-grown pig, castrated when a few weeks old, the corresponding parts of the genital apparatus are as follows:—

The Prostate Gland.

The prostate gland in the full-grown pig is so small and so closely adherent to the dorsal wall of the urethra that it is with difficulty recognised. After dissection from the surrounding tissue, it is seen as a circular, disc-like swelling, with a convex outer surface. It measures about $\frac{1}{2}$ inch in diameter and about $\frac{1}{4}$ inch in thickness (see Pl. XI. fig. 5). On transverse section it is seen to be quite distinct from the wall of the urethra its ducts traversing the central parts and the glandular substance occupying the periphery. Under the microscope, the gland is seen to be composed of slightly branching tubules, embedded in and widely separated from one another by an abundant fibrous stroma. The gland tubules are rudimentary, and but slightly branched; they are lined by a single layer of subcolumnar cells which surround a small lumen. The intertubular connective tissue is chiefly fibrous. In the substance of the larger septa there are unstriated muscular fibres which are in a more or less dwindled state (see fig. 8).

The Vesiculæ Seminales.

The vesiculæ seminales are represented by two small, flat, bean-like masses which are firm and composed of small compact lobules held together by means of loose areolar tissue. Each lobule is 1 inch long, and $\frac{1}{3}$ to $\frac{1}{4}$ of an inch broad (see Pl. XI. fig. 4). The gland is composed of a number of tubules with thick walls consisting in the main of fibrous connective tissue, with a few unstriated muscular fibres. These tubules are lined by a single layer of sub-columnar cells. In many of the tubules there is a small lumen, but in others the interior is filled with irregular-shaped cells. The tubules, which are grouped together into a lobule, are connected by somewhat dense fibrous connective tissue, but the lobules themselves are connected only by a small amount of loose areolar connective tissue.

Cowper's Glands.

Cowper's glands are small elongated pyramids. They measure 2 inches in length and $\frac{1}{4}$ of an inch in thickness at the lower and larger end (see Pl. XI. fig. 4). The striped muscle on the outer surface is correspondingly small. They are mainly com-

posed of ducts, which are filled with a mucoid secretion. The peripheral part of the gland is composed of numerous closely-packed vesicles which have hardly any lumen; these are lined by a single layer of subcolumnar cells with small nuclei near their attached ends and with clear protoplasm (see fig. 10).

The Membranous Urethra.

The intra-pelvic portion of the genital part of the urethra is comparatively of small size, being no more than $\frac{1}{2}$ inch in diameter. The constrictor urethræ, though contracted to its full extent, as the urethra is almost closed and not open as in the specimen from the boar, measures only 4 mm. in a radial direction in front, and it appears tough and fibrous, unlike the healthy, well-formed muscle of the boar. The submucous glandular layer is also of small size, measuring in a radial direction only 3 mm. (see fig. 6).

Under the microscope, the muscle is found to be composed of fibres that are about half the size of the normal; they are strongly fibrillated in a longitudinal, but only feebly, if at all, in a transverse direction. There is, indeed, the absence of the transverse striation so characteristic of well-formed striped muscle.

In the submucous glandular tissue, the glandular partitions are not nearly so broad, owing to the comparatively small number of tubules; these are not very branched, but they are like those seen in the boar, although more widely separated by fibrous connective tissue.

Special Muscles of the Penis.

The special muscles of the penis, like the constrictor urethræ, are small, pale and fibrous.

REMARKS.

We see, therefore, that the accessory sexual organs reach their full development only when the testes are present. In the full-grown pig, castrated when only a few weeks old, the prostate gland is very small and dense, and the gland tubules are very rudimentary. The vesiculæ seminales, which are so large in the boar, are extremely small in the pig; the tubules are few in number, of small size, and devoid of secretion. The Cowperian

glands are similarly reduced. The urethra, with its striped muscle—the constrictor urethræ—is also of small size in the pig, owing to the smallness of the muscle that surrounds it, and of the undeveloped glandular submucous tissue. The chief function, then, of the prostate gland, vesiculæ seminales, Cowper's glands, the glands in the submucous tissue of the intra-pelvic portion of the genital part of the urethra, and of the constrictor urethræ is genital, or sexual. These several glands serve to form a secretion, which probably mingles with the semen, and gives it some properties that it alone does not possess. The chief use of the constrictor urethræ is doubtless the expulsion of the mixed seminal fluid from the urethra. In the boar, the urethra at and immediately in front of the place where the vasa deferentia open into it is dilated and very capacious. This dilatation of the urethra closely resembles the prostatic dilatation of the human urethra.

Are these differences between the several glands in the boar and pig the result of developmental growth ceasing early, or are they due to the failure of the maintenance of full size and vigour? In all probability, indeed almost certainly, this condition of the glands results from a cessation of developmental growth before puberty, and from the absence of the stimulus to further growth rather than from a retrogression after the attainment of full growth. In no stage of the life of a castrated animal do we find the sexual glands fully developed; rather are they small, dwindled, and fibrous.

The only difference between the pig and the boar is, as I have said before, that the former is deprived in early life of his testes, and that the latter retains them. No one can, it seems to me, doubt but that complete castration prevents the full development of the accessory sexual glands and of the muscles of the urethra and penis, the function of which is chiefly genital. I have shown elsewhere that if the testes be removed, say from a full-grown dog, the same glands dwindle and become fibrous, and the glandular tubules become reduced to a simple state,—a condition similar to that just described in the pig.

The absence of the testes prevents, therefore, the development of the accessory sexual glands.

Is this determined by the influence of the central nervous

system, or does it arise from the absence of that secretion which the testes, like the thyroid for example, gives to the system? It is at present impossible to give a satisfactory answer to this question, and the problem is one that will prove difficult to solve.

DESCRIPTION OF PLATE XI.

Fig. 1. Front view of urogenital organs of a full-grown boar. *T*, testes; *Ep*, epididymis; *V.D*, vas deferens; *U.Bl*, urinary bladder; *Ur*, ureter; *V.S*, vesiculæ seminales; *C.Gl*, Cowper's gland; *Mem.Ur*, membranous urethra. Reduced to nearly $\frac{1}{4}$ nat. size.

Fig. 2. Posterior view of urethra of a boar, to show prostate gland. *Pr.Gl*, prostate gland. Nat. size.

Fig. 3. Transverse section through the membranous urethra of a boar. *Const.Ur*, constrictor urethræ; *Muc.Memb*, mucous membrane of urethra containing numerous glands.

Fig. 4. Front view of urogenital organs of a full-grown pig. Half nat. size.

Fig. 5. Posterior view of urethra of a pig, to show prostate gland. Nat. size.

Fig. 6. Transverse section through the membranous urethra of a pig. Nat. size.

Fig. 7. $\times 120$. A group of tubules of the prostate gland of a full-grown boar. (*a*) tubules lined by a single layer of columnar epithelial cells; (*b*) inter-tubular septa, in which blood-vessels run; (*c*) inter-lobular septa which contain unstriated muscular fibres.

Fig. 8. $\times 120$. A group of undeveloped tubules from the prostate gland of a full-grown pig. (*a*) tubules lined by a single layer of small cubical cells; (*b*) inter-tubular fibrous connective tissue. The inter-lobular septa in which the unstriated muscular fibres lie are not shown.

Fig. 9. $\times 120$. A group of tubules of Cowper's glands of a full-grown boar. (*a*) tubules lined by a single layer of tall columnar cells like those of a mucous gland; (*b*) inter-lobular connective tissue.

Fig. 10. $\times 120$. A group of tubules of Cowper's glands of a full-grown pig. (*a*) tubules lined by small, sub-columnar cells with clear protoplasm; (*b*) inter-tubular connective tissue; (*c*) large duct.

ON THE OCCURRENCE OF AN APPARENTLY DISTINCT PREVOMER IN GOMPHOGNATHUS. By R. BROOM, M.D., B.Sc.

AMONG the Theriodonts of S. Africa recently described and figured by Prof. Seeley,¹ the most interesting forms to the student of mammalian morphology are the allied genera Gomphognathus and Cynognathus. Of each of those almost perfect skulls have been discovered, and an examination of them throws light on a number of intricate points in mammalian structure. In one skull of Gomphognathus the anterior palatal region is well preserved, and the matrix has been removed with such care that the parts are seen in almost as perfect condition as in a recent skull. This region, in this well preserved specimen, is thus described by Seeley²:—"The palate has a median choana, which is ovate. Through it a cylindrical bone like a unenamelled tooth descends, so as to project upon the palate. It is in the position of the anterior end of the vomer displaced, but there is no proof of its real nature to be obtained without destroying the specimen by slicing it."

While recently in London, I had the opportunity, through the kindness of Mr A. S. Woodward, of examining the original specimen. Seeley's description, apart from the figure, hardly conveys a clear idea of the structure; and with his view that it is in the position of the anterior end of the vomer displaced, I am not inclined to agree.

The whole palatal region, from the posterior nares to the front of the snout, agrees closely with the mammalian condition, a perfect secondary palate being formed by maxillary and palatine plates. Behind the posterior edge of the palate there is displayed a well developed median ridge, dividing the two posterior nares. This median ridge unquestionably belongs to the vomer proper—the homologue of the mammalian vomer—as is recognised by Seeley. The premaxillary portion of the palate

¹ "Researches on the Structure, etc., of Fossil Reptilia," *Phil. Trans.*, 1894-95.

² *Ibid.*, part ix. sect. 4, "On the Gomphodontia," *Phil. Trans.*, 1895, B., p. 16.

is better developed than in the majority of mammals, and presents a few points of difference from the ordinary mammalian type. In the 'median choana' of Seeley there can be little or no doubt we have the anterior palatine foramina, separated by the median element. Though Seeley refers to this latter as a single bone, there is in the original specimen an indication of a median suture dividing the apparently single bone into two halves. These closely united elements pass together through the oval median space, forwards and slightly downwards, causing the anterior part to project on the palate as a rounded papilla. Behind the median choana the premaxillaries again meet in the middle line with two large palatal plates.

With regard to Seeley's suggestion that the median process may be the anterior end of the vomer displaced, it may be noted (1) that the vomer in its posterior parts is in undisturbed relation with the surrounding parts, so that the anterior part could only be displaced by being broken away from the main body, a fracture which could hardly take place without some evidence of it in the bones surrounding the vomer, but all of which are practically intact; (2) that in no known mammal, with distinct anterior palatine foramina, does the vomer appear on the palate between them; and (3) that the anterior edge of the median elements is rounded and smooth, which would not be the case had it formed a suture with the premaxillaries.

In almost all mammals there is found between the two anterior palatine foramina a paired osseous element, which develops originally as a splint on the inner and under side of Jacobson's cartilage. In the large majority of forms this element is either formed in connection with the premaxillary, or is early united with it, forming its palatine process. In a very few mammals it remains throughout life quite distinct from the premaxillary, as in *Ornithorhynchus*, where it forms the so-called 'dumb-bell-shaped bone,' and in the little cave bat, *Miniopterus schreibersii*, where a condition is found much like that in the platypus;¹ while in forms where Jacobson's organ is not developed the element is usually quite absent, *e.g.*, *Pteropus*,

¹ "On the Homology of the Palatine Process of the Mammalian Premaxillary," *Proc. Linn. Soc. N.S.W.*, vol. x., 1895, p. 477.

Nyctophilus, etc. For this element I have proposed the name of 'prevomer.'

There seems to me scarcely any doubt that in the bone under consideration in *Gomphognathus* we have this prevomerine element, so generally present in mammals as the palatine process of the premaxillary. In the relation to the front and lateral parts of the premaxillary the agreement is complete, and there is little doubt that the naso-palatine canals passed up by the sides of the median bones, as is the case in mammals. The meeting of the premaxillaries behind the foramina in *Gomphognathus*, is rather a reptilian than a mammalian character (*cf.* *Crocodylus*). In a few Edentates and Rodents, however, the condition is still met with, and there is a very marked tendency to the same condition in some species of *Macropus*. In the Monotremes, the premaxillaries are edentulous and rudimentary; but in the fact that behind the naso-palatine canals the outer parts of the nasal floor cartilages sweep inwards and meet each other, we have a strong suggestion that in the earlier forms the premaxillaries likewise united behind the canals, after the manner in *Gomphognathus*. The downward projection of the prevomer is more marked than in any mammal, though in the prevomer of *Ornithorhynchus* there is an indication of a similar development, while the very large papilla in some marsupials (*e.g.*, *Phascodomys*) is probably also related to this downward projection.

We may thus conclude that the bony element in *Gomphognathus*, occupying a similar position to the palatine process of the premaxillary in the ordinary mammal, and bearing apparently similar relations to the naso-palatine canal, is the homologue of that process, and is thus a true prevomer. Its apparent independence of the premaxillary is strongly in support of the view that the premaxillary palatine process in mammals generally is morphologically a vomerine element, the homologue of Lacertilian so-called 'vomer,' and not a part of the premaxillary proper, though usually ossified in connection with it, or early united to it. In the Monotremata, whose affinities with the Theromora have long been recognised, there is no palatine process to the premaxillary in either of the known genera. In *Ornithorhynchus* the prevomer is a distinct element, as in *Gomphognathus*; in *Echidna* it is absent.

ON AN APPARENTLY HITHERTO UNDESCRIBED
NASAL-FLOOR BONE IN THE HAIRY ARMADILLO.
By R. BROOM, M.D., B.Sc.

THROUGH the kindness of Mr F. E. Beddard, I recently obtained the head of an adult *Dasypus villosus*, in order to make an examination of the condition and relations of Jacobson's organ in a typical member of the Edentata. I have since made sections of the whole snout, and in examining these have come across a very remarkable and apparently hitherto unnoticed bone. This is a little paired bone lying in the nasal floor, and extending from the plane of the hinder part of the anterior nares to about the plane passing through the middle of the papilla. Its being for a large part hidden by the palatal part of the premaxillary probably accounts for its having been missed by Parker in his dissection of the young *Dasypus* figured in his Monograph on the development of the Edentate skull.¹

In the transverse plane passing through the posterior border of the anterior nares, the nasal septum is moderately developed as a uniformly thick vertical plate, giving off above two well developed alinasals, which pass outwards in contact with the well ossified nasals. From near the outer ends of these there passes downwards and inwards, on each side a sort of imperfect turbinal, supported by a cartilage, which at this plane is detached from the alinasal; this is the cartilage of the nasal valve. Near the lower part of this imperfect turbinal, there is a small inner and upper process, and in it lies the anterior part of the bone to be described. This small inward and upward passing process, when followed back, is found to be a continuation of the ridge of the inferior turbinal. On this plane the anterior end of the little bone is elevated to the level of the middle of the nasal septum.

As we examine more posterior planes we find the ridge and bone passing more into the true nasal floor. For some little distance the bone practically rests on the lachrymal duct.

¹ *Phil. Trans.*, 1886.

In the plane passing through the anterior part of the papilla the following condition is found. The septum, which anteriorly was a uniform cartilage, is here found giving off its lower third, which soon becomes divided vertically into two lateral basal cartilages. The upper undivided part is the true nasal septum; the lower parts are due to a peculiar development of the trabecular cornua, which in most mammals turn back by the sides of the septum, but which here pass back below the base of the septum. Another peculiarity is, that whereas in almost all mammals each trabecular cornu gives rise, in the anterior part at least, to a lateral nasal-floor cartilage, as well as to the septal part which becomes Jacobson's cartilage, here there is on this plane no nasal-floor cartilage. The place that would be occupied by the nasal-floor cartilage is, however, occupied by the bone under consideration; but whether the absence of the cartilage has given rise to the bone, or the presence of the bone has aborted the cartilage, I am not in a position to say. Anterior to this plane the bone is only present as a comparatively slender process, following the course of the lachrymal duct, but here it suddenly sweeps across the space between the duct and the base of the trabecular cornu, forming a complete floor to the nasal passage. This is the widest part of the bone, it being here about 3 mm. broad. On this plane the palatal part of the premaxillary is not yet encountered.

Behind this plane the nasal-floor bone becomes gradually narrower. At its outer part it becomes removed from its relations with the lachrymal duct, the alinasal taking its place both as a support to the anterior part of the inferior turbinal process and to the duct, while internally the recurrent cartilage encroaches on the bone with a small nasal-floor cartilaginous process.

In the plane passing through the anterior region of the palatal part of the premaxillary the bone has become distinctly reduced in width. It practically rests on the premaxillary, though quite distinct from it, and completes the nasal floor by filling up the small space between the inner and outer cartilages.

On reaching the plane of the middle of the papilla the bone ends, and its place is taken by the outer and inner cartilages

meeting, and forming a perfect cartilaginous nasal floor as in ordinary mammals.

In considering the significance of the bone, it is easier at present to say what it is not, than what it is. Though bearing close relations to the cartilages of the nasal wall throughout its whole extent, the bone is apparently not formed in cartilage, and probably not as a splint to cartilage.

The first thought that would occur to one as to its homology would be a comparison with the dumb-bell-shaped bone in *Ornithorhynchus*, but on examination it will be seen that there is no relationship whatever between the two. The dumb-bell bone is known for certain to be the homologue of the palatine process of the premaxillary, which exists quite distinctly in *Dasypus* further back in the normal way. Nor can any homology be made out with the prenasal bone of the pig, as the bone under consideration has no connection with the prenasal cartilage or the nasal septum. The relations of the anterior part of the bone with the inferior turbinal process suggest that it might be a rudimentary inferior turbinal bone. This view is also found to be untenable, as in no known mammal does the inferior turbinal extend so far forward, and also as there is in *Dasypus* a well developed inferior turbinal bone posteriorly. Another view is suggested by the fact that in the Monotremes the premaxillary is developed as upper and lower plates separated by the large rostral cartilage, and the posterior relations of the bone seem to indicate that we might possibly have in the premaxillary proper the lower and in the nasal-floor bone the upper plate of the Monotremes. Though the position of the anterior part of the bone on the upper wall of the external nasal opening appears against this view, it is not open to such serious objections as are the other views. At present, however, till the development of the bone is known, it will be safest to suspend judgment on the question of its homology, and to refer to it merely as the *nasal-floor bone*.

**AN ABNORMAL MUSCLE OF THE HAND, WITH
REMARKS ON THE COURSE OF THE RADIAL
ARTERY.** By T. WARDROP GRIFFITH, *Professor of Anat-
omy, Yorkshire College, Leeds.*

DURING the winter session of 1895-96 my attention was called to the presence of an abnormal muscle in the hand of one of the subjects; and as I have been unable to find a description of a similar abnormality, I desire to put it on record. For some years, also, I have been struck with the variations that occur in the relation of the radial artery to the muscles of the thumb; and in dissecting this blood-vessel, I have had impressed on my mind the presence of a ligament uniting the proximal ends of the first and second metacarpal bones, which does not seem to have received the attention it deserves. I purpose, therefore, appending to the description of the abnormal muscle a few remarks on these two points.

The body showing the abnormality was that of a well-developed male. In the left hand the abductor, opponens, outer head of flexor brevis, adductor obliquus, and adductor transversus were normal. The inner head of the flexor brevis was wanting. The first dorsal interosseous, which presented the abnormality, was arranged as follows. The outer head was normal, arising from the greater part of the inner border of the first metacarpal bone, and, as it often does, from the ligament uniting that with the second. The inner head consisted of two portions, which were quite distinct from one another: (*a*) a dorsal part, coming from the outer aspect of the dorsal ridge of the 2nd metacarpal, and posteriorly from the enlarged carpal end of the bone; and (*b*) a palmar part, arising from a limited area on the palmar and radial aspect of the 2nd bone, about $\frac{3}{4}$ " from its carpal extremity. Parts (*a*) and (*b*) were quite separate, and at their insertion they were kept apart by the portion now to be described. This was in bulk equal to (*a*) and (*b*) together, and arose behind from the palmar aspect of the ligament uniting the 1st and 2nd bones, and by a tendinous band which passed from the ridge of the trapezium round the inner side of the

upper end of the 1st metacarpal. I may here mention that the flexor carpi radialis gave off a small slip to the ridge of the trapezium as it was entering the groove in that bone, but my dissection did not reveal any distinct connection between this slip and the tendinous band of origin just noticed. Arising in this way, the muscle, on being traced forwards, was found to divide into two parts: (1) a small slip, which widened, and was inserted for nearly one inch into the radial aspect of the index metacarpal, just in front of the origin of the dorsal part, beginning about $\frac{1}{4}$ " in front of the carpal end; and (2) a large part,

slip

slip

is of
the muscle

VII

which passed on freely, and was inserted into the outer aspect of the base of the 1st phalanx of the index finger, behind the palmar slip, and in front of the conjoined insertion of the dorsal part and the outer head, of which the latter was superficial. The radial artery came forward on the ulnar side of this abnormal muscle.

In the right hand a somewhat similar condition was found. Thus the abductor, opponens, outer head of flexor brevis, adductor obliquus, and adductor transversus were all normal. The inner head of the flexor brevis was extremely small, but normal in origin and insertion. The outer head of the 1st dorsal interosseous was similar to that just described on the left side. The

inner head was again found to consist of two portions,—a dorsal, as on the left side, and a palmar, distinctly larger than that on the left side, but arising, like it, from the anterior and radial aspect of the index metacarpal. These two heads were quite separate, except at their insertion, and between them was found a very small fibro-muscular slip, whose origin had been destroyed, but which, on being traced forwards, partially blended with the dorsal head towards its insertion, and partially was inserted, in front of the origin of that head, into the dorsal ridge of the index metacarpal. This fibre-muscular band seemed to represent the abnormal muscle of the left side.

I now examined four hands in the dissecting-room, with special reference to the 1st dorsal interosseous muscle, with the following result:—

CASE I.—(Left hand).—Outer head normal, arising from 1st metacarpal and from the above-noted ligament uniting 1st and 2nd bone. The inner head consisted of a dorsal part arising from the radial side of the dorsal ridge, and a palmar part arising from about the middle third of the palmar ridge. These two parts were quite separate, except at their insertion.

CASE II.—(Left hand).—Outer head normal. Inner head consisted of a dorsal part, which arose from the proximal extremity of the 2nd metacarpal bone, and part of its dorsal ridge, and of a palmar part, which was deeper, and extended from the dorsal ridge behind to the palmar ridge in front. Arising from the neighbourhood of the proximal end of the 1st bone was a small muscle, which was soon joined by a slip from the proximal end of the 2nd bone, and pressed along to join with the outer head.

CASE III.—Outer head normal. Inner head extended from dorsal to palmar ridge, and could not be distinctly separated into two.

CASE IV.—Outer head normal. Inner head consisted of small dorsal part attached to the proximal end of index metacarpal, to part of dorsal ridge, and to the ligament uniting 1st and 2nd bones. This was readily separated from a mass of flesh, embracing the os metacarpi indicis from its lateral to its palmar ridge. This consisted of several portions, the separation of which would, however, have been artificial.

The above observations, fragmentary and imperfect though

they are, may possibly induce others to look into the anatomy of the 1st dorsal interosseous muscle.

I do not think any of the text-books give us accurate information as to the course of the radial artery after it has passed between the two heads of the 1st dorsal interosseous muscle, and prior to its appearance in the palm of the hand between the margins of the adductor obliquus and adductor transversus, where it most usually is found.

In the latest edition of *Quain* (vol. ii. pp. 237 and 238) are two diagrams by Mr Thane, showing respectively the point of appearance of the artery in the palm between the two adductors and the interval between the inner head of the short flexor and adductor obliquus, through which the artery passes from behind. It will occur to most, that if the artery plunges forward at the radial or upper margin of the adductor obliquus, it is rather strange that it should appear at the ulnar or lower margin in the palm. Still, this is what it often appears to do, and the explanation is, I find, what I anticipated; for manifestly, if the diagrams are correct,—and knowing Mr Thane's accuracy, I had not much doubt on that point,—then, to fulfil the conditions, the artery must in such cases pass through the substance of the adductor obliquus.

In a series of dissections, I found that the radial artery passed from the radial or upper margin of the adductor obliquus through its substance to the ulnar or lower; in others, that it lay altogether behind the muscle, and then passed forwards between it and the adductor transversus, while in other cases it passed from the radial margin through the muscle to its anterior surface.

In describing the muscles, I have made frequent reference to a ligamentous band uniting the first and second metacarpal bones, passing from the ulnar side of the proximal extremity of the 1st to the 2nd, close to the insertion of the extensor carpi radialis longior. I am confident we are all acquainted with this band, which is constant and strong, which is tightened on abduction of the thumb, and can frequently be made out during life.

This band is, I find, carefully described and figured by Humphry in his *Treatise on the Human Skeleton* (1858 edition, p. 433, and fig. 2, plate xxxiii.).

It is also figured by Allen Thomson in the various editions

of *Quain*, in Gray's *Anatomy*, and in Macalister's text-book. It is not represented in Morris's *Work on the Joints*, nor in Morris's *Anatomy*. In the letterpress no mention of it is found in Quain, Gray, Cunningham, Morris's books, or Ellis. Cruveilhier, indeed, states that the metacarpal bones are united proximally, but the context does not guide us as to whether he means the four or five bones. Macalister states that the bones are united proximally, but the mention of synovial membranes would point to his referring only to the four inner bones.

Since the above was written (the paper was on the list for the May meeting of the Anatomical Society), a good description of the band, with a photograph of it, has appeared in Cleland and Mackay's work on *Anatomy*, published in September of this year. They suggest for it the name of the internal metacarpal ligament of the thumb. They say it "seems to have escaped notice," but in this they are not quite accurate; for, as I have shown above, it is figured in several of the standard text-books, and by Professor Humphry it has been accurately figured and described.

VARIATIONS OF RIBS IN THE PRIMATES, WITH
ESPECIAL REFERENCE TO THE NUMBER OF
STERNAL RIBS IN MAN. By A. F. TREDGOLD, London
Hospital, London.

MAN has normally twelve ribs, divided into 7 True, 3 False, and 2 Floating; but it has been repeatedly noticed that deviations from this arrangement may occur, as follows:—

1st, *In the number of 'True' or vertebro-sternal.* These may be (a) increased on one or both sides by the 8th or upper false rib becoming a true one, owing to its having a direct attachment to the sternum; or (b), less often, diminished by reduction in the number of ribs which reach the sternum.

2nd, By an alteration, generally increase, in the *number of floating ribs*, in which case the 10th rib, instead of uniting with the one above it, remains free, like the 11th and 12th. Or, less often, by a decrease, in which case the last but one, or even the last, may be connected to those above, so that there are no 'floating' ribs.

3rd, By an alteration in the *total number of ribs*,—(a) either by an increase, owing to the presence of an additional one in the cervical or lumbar regions, and this may be on one or both sides, or (b) by a decrease in the number, and this more frequently occurs below.

All these abnormalities have been pointed out, although perhaps the 1st and 3rd more frequently; and of these two, probably the 1st—*or the attachment of the 8th costal cartilage to the sternum*—has received the closest attention. Perhaps this is due in great measure to the singular fact that it has a distinct preference for the male sex and the right side. The cause of this preference has been investigated by many inquirers, and various hypotheses have been advanced in explanation. That given by Professor Cunningham, that it is due to the greater use which man makes of his right arm, certainly seems the most reasonable one; but I believe that it is not correct, and that

another explanation may be given which is probably more near the truth.

From a close investigation of specimens from ten genera of the order Primates, one arrives at the following conclusions:—

1st, That a gradual, but marked *reduction* takes place in the *total number of ribs* as we rise in the animal scale.

2nd, That a coincident and proportional *reduction* takes place in the *number of sternal ribs* with rise in the animal scale.

3rd, That the 8th rib tends, from a sternal, to become a costal one; and that these various changes all unite to bring about—

4th, A gradual shortening of the thoracic cavity from below.

The specimens examined were obtained from—

1. The Museum of the Royal College of Surgeons.
2. The Natural History Museum, S. Kensington.
3. Dissections by Dr A. Keith in Siam.
4. A few from the London Hospital and other sources.

Unfortunately, about 50 per cent. of the Museum specimens were useless for this purpose, the costal cartilages being either missing entirely, their place being taken by ingenious compounds of wax, clay, cotton wool, or even steel springs; or if present, bearing evident signs of having been tampered with. Care has been taken to exclude all of doubtful condition, and the results given are only of those specimens which may be considered quite reliable.

The following number of cases were examined in each genus:

| | |
|--------------------------|-----------------|
| Lemuroidæ, | 9 specimens. |
| Platyrrhini, | 9 " |
| Macaci, | 27 " |
| Cercopithecii, | 6 " |
| Semnopithecii, | 30 " |
| Gibbons, | 16 " |
| Orang, | 12 " |
| Chimpanzee, | 17 " |
| Gorilla, | 7 " |
| Man { dark, | 5 " |
| { light, | 230 " |
| Total, | <hr/> 368 <hr/> |

The following tables give the arrangement found to exist in

each genus,—for convenience of comparison, given in percentages.

I.—*Lemuroidea*. (No. of Cases, 9.)

| | | | |
|--------------------------------------|-----------------------------------|--------------------|---------------|
| Total No. of Ribs, | . 15 in 45 p.c. | 12 * in 18 p.c. | 16 in 15 p.c. |
| | | 13 in 11 p.c. | 14 in 11 p.c. |
| No. of Sternal, | . . 11 and 12 in 44 p.c. | 9 in 33 p.c. | |
| | | 8 in 22 p.c. | |
| No. of Floating, | . . 0 in 66 p.c. | 1 and 2 in 33 p.c. | |
| Attachment of 8th Costal Cartilage,— | Sternal in 100 p.c.; Costal in 0. | | |

* A rudimentary 13th pair.

Note.—This, the lowest order of the Primates, although apparently subject to considerable variation, well shows three points: 1. On the average there are more ribs than in any other genus of the order. 2. The shape of the rib tends much more to resemble that of the Carnivora. 3. The 8th rib invariably reaches the sternum.

II.—*Platyrrhini*. (No. of Cases, 9.)

| | | |
|--------------------------|---------------------------------------|--|
| Total No. of Ribs, | . 13 * in 77 p.c. | 14 † in 23 p.c. |
| No. of Sternal, | . . 9 in 55 p.c. | 6 and 7 occasionally, 8 frequently. |
| No. of Floating, | . . 0 in 55 p.c. | 1 and 2 in 45 p.c. |
| Attachment of 8th C.C.,— | Sternal in 66 p.c.; Costal in 33 p.c. | |

* In one of these a rudimentary 14th lumbar pair.

† In one of these the 14th pair are quite rudimentary, being only 2 cm. long, and in another there is a 15th lumbar rib on the left side.

Note.—This order is exceedingly comprehensive, so that considerable variations occur.

III.—*Cercopithecii*. (No. of Cases, 6.)

| | | |
|--------------------------|-------------------------------------|---------------|
| Total No. of Ribs, | . 12 in 66 p.c. | 13 in 33 p.c. |
| No. of Sternal, | . . 8 in 100 p.c. | 9 in 16 p.c. |
| No. of Floating, | . . 2 in 66 p.c. | 3 in 33 p.c. |
| Attachment of 8th C.C.,— | Sternal * in 100 p.c.; Costal in 0. | |

* The 8th pair are fused together across the base of the ensiform.

IV.—*Macaci*. (No. of Cases, 27.)

| | |
|--------------------------|--|
| Total No. of Ribs, | . 12 * in 100 p.c. |
| No. of Sternal, | . . 8 in 96 p.c. 7 in 4 p.c. |
| No. of Floating, | . . 2 in 76 p.c. 0 in 24 p.c. |
| Attachment of 8th C.C.,— | Sternal † in 96 p.c.; Costal in 4 p.c. |

* In one of these a rudimentary 13th lumbar pair present.

† The two fuse together across the base of the ensiform.

V.—*Semnopithecus*. (No. of Cases, 30.)

Total No. of Ribs, . . . 12* in 100 p.c.
 No. of Sternal, . . . 7 in 83 p.c. 8 in 14 p.c. 6 in 3 p.c.
 No. of Floating, . . . 3 in 48 p.c. 2 in 40 p.c. 0 in 12 p.c.
 Attachment of 8th C.C.,—Costal in 83 p.c.; Sternal† in 17 p.c.

* In one of these a rudimentary 13th lumbar pair present.

† In one of these the 8th C.C. reached the ensiform by fibrous tissue only, and in another it ended loosely in front of the ensiform.

VI.—*Gibbons*. (No. of Cases, 16.)

Total No. of Ribs, . . . 13* in 88 p.c. 14† in 12 p.c.
 No. of Sternal, . . . 7 in 82 p.c. 8 in 18 p.c.
 No. of Floating, . . . Usually 3 or 4.
 Attachment of 8th C.C.,—Costal in 82 p.c.; Sternal‡ in 18 p.c.

* In one of these the 13th is absent on the right side.

† In one instance the 14th pair were quite rudimentary.

‡ When the 8th rib is a true one in the gibbon it does not usually fuse across the base of the ensiform as in the monkeys, but either ends by a free extremity at the outer side of the base, or is connected with the 7th at this spot.

VII.—*Chimpanzee*. (No. of Cases, 17.)

Total No. of Ribs, . . . 13* in 80 p.c. 14 in 20 p.c.
 No. of Sternal, . . . 8 in 54 p.c. 7 in 46 p.c.
 No. of Floating, . . . Varies from 1, 2, 3, 4. Not sufficiently reliable for figures.
 Attachment of 8th C.C.,—Sternal† in 54 p.c.; Costal‡ in 46 p.c.

* One specimen had a rudimentary cervical rib on each side attached to the contiguous portions of 6 and 7 C. vertebrae; the 1st sternal rib in the same case articulating with the 7th and 8th vertebrae.

† In two of the cases classed as having 8 true ribs, this was only so on the right side, the 8th cartilage on the left side being 2 cm. from the sternum,—one a male, the other a female.

‡ When the 8th rib is costal in the chimpanzee it is attached to the 7th C.C. at a distance of 1 to 2 inches from the sternum.

Note.—In connection with the chimpanzee and gorilla, there are two other points worth noting:—(1) junction between the 6th and 7th costal cartilages is frequently observed; and (2) that the sacrum frequently consists of six pieces.

VIII.—*Gorilla*. (No. of Cases, 7.)

Total No. of Ribs, . 13 * in 86 p.c. 12 † in 14 p.c.
 No. of Sternal, . . 7 in 72 p.c. 8 in 28 p.c.
 No. of Floating, . . Varies from 1, 2, 3.
 Attachment of 8th C.C.,—Costal ‡ in 72 p.c.; Sternal in 28 p.c.

* One case having a rudimentary left lumbar rib $1\frac{1}{2}$ inches long.

† One case having 12 ribs on right side and only 11 on left.

‡ The 8th cartilage is usually fused with the 7th from $1\frac{1}{2}$ to 2 inches from the sternum.

IX.—*Orang*. (No. of Cases, 12.)

Total No. of Ribs, . 12 * in 84 p.c. 13 in 16 p.c.
 No. of Sternal, . . 7 † in 92 p.c. 6 in 8 p.c.
 No. of Floating, . . 2 and 3 in 60 p.c. 0 in 30 p.c. 4 in 10 p.c.
 Attachment of 8th C.C.,—Costal ‡ in 100 p.c.

* In one of these there were but 11 ribs on the left side, and the 12th right was rudimentary, the same ape having but 6 true ribs on each side.

† A specimen with 7 true ribs on the left side and but 6 on the right.

‡ In one of these the 8th cartilage touched the sternum on the *left* side, on the right side being attached to the 7th as usual.

In the remaining cases the 8th rib cartilage is attached to the 7th at a distance of from $\frac{1}{2}$ to 3 inches from the sternum : usually the distance is equal on the two sides ; in some it is nearer on the right, in others on the left. I cannot find that it has any preference for either side or sex.

Note.—The reduction of ribs appears to have gone further in the orang than in any other ape. There are not often more than 12 ribs—rarely more than 7 true, and occasionally but 6. Probably connected with the great length and movement of the arms.

X.—*Man, dark skin*. (No. of Cases, 5.)

Total No. of Ribs, . 12 in 100 p.c.
 No. of Sternal, . . 8 in 60 p.c. 7 in 40 p.c.
 No. of Floating, . . Varies from 1, 2, 3.
 Attachment of 8th C.C.,—Sternal in 60 p.c.; Costal in 40 p.c.

Note.—It is unfortunate that the available specimens are so few ; but three-fifths of these had 8 true ribs present on both sides, and I think there can be very little doubt that this abnormality is really more common amongst the dark-skinned races. Also three-fifths of the cases had six pieces in the sacrum.

Dr Lamb of Washington (*Nature*, Nov. 1, 1888) records twelve cases of 8 true ribs in man : eleven of these were Negroes, the twelfth being an American Indian.

Man, light skin (No. of Cases, 23.)

Total No. of Ribs not examined.*

Males

| | | | | |
|-----------------|------------------------|----------------|----------------|--|
| No. of Sternal— | <i>Right</i> , . | 7 in 88.2 p.c. | 8 in 11.8 p.c. | (Collective Investigation Committee |
| | <i>Left</i> , . | 7 in 91.2 p.c. | 8 in 8.8 p.c. | |
| | <i>Bilateral</i> , . | 7 in 90 p.c. | 8 in 10 p.c. | Tredgold |
| | ? <i>Bilateral</i> , . | 7 in 100 p.c. | 8 in 0 p.c. | Hyrtl |

Females

| | | | | |
|-----------------|------------------------|----------------|---------------|--|
| No. of Sternal— | <i>Right</i> , . | 7 in 94.5 p.c. | 8 in 5.5 p.c. | (Collective Investigation Committee |
| | <i>Left</i> , . | 7 in 100 p.c. | 8 in 0 p.c. | |
| | <i>Bilateral</i> , . | 7 in 90 p.c. | 8 in 10 p.c. | Tredgold |
| | ? <i>Bilateral</i> , . | 7 in 90 p.c. | 8 in 10 p.c. | Hyrtl |

Attachment of 8th C.C. Average,—Sternal in 10 p.c.; Costal in 90 p.c.
Costal more frequent in males, and on the right side.

* Total ribs—generally 12, rarely 13, and frequently the 13th pair are quite rudimentary; so that the average may probably be taken as 11.9.

Notes.—I have taken the liberty of using, in addition to my own cases, those recently published by the Collective Investigation Committee (1895–6); those of Professor Hyrtl of Vienna; and of Professor Cunningham.

There are considerable differences. Thus, Professor Hyrtl finds that out of thirty subjects an 8th true rib occurs three times, but in females only. Out of twenty-four cases I find it to occur equally in male and female, and to be bilateral.

Professor Cunningham's figures (70 cases) confirm those of the Collective Investigation Committee in so far as the abnormality occurs more frequently in the male and on the right side; but he places the percentage much higher,—finding an 8th true rib in as many as 20 per cent. of cases.

In two of the cases recorded by the Collective Committee there were but 6 true ribs (2 per cent.).

To facilitate comparison of these figures I have drawn up the following table. It gives, at a glance, the numerical relations which exist between *total*, *true*, and *floating* ribs in each genus of the Primates.

The figures represent the *average* number of each in the class, and are obtained as follows:—The total number of ribs present on one side in all the specimens of Lemuroidæ is found to be

127: there are 9 individuals, which gives $1\frac{2}{3}^7 = 14.1$ as the average number of ribs in the group. Sternal and floating ribs are obtained in the same way. The number of cases of 8 true ribs is given in percentages.

TABLE I.

| | Monkeys. | | | | | Apes. | | | | Man. | |
|--------------------------------------|------------|--------------|---------------|---------|---------------|----------|-------------|----------|--------|-------------|--------------|
| | Lemuroide. | Platyrrhini. | Cercopitheci. | Macaci. | Semnopitheci. | Gibbons. | Chimpanzee. | Gorilla. | Orang. | Man (dark). | Man (light). |
| Total number of Ribs, | 14.10 | 13.50 | 12.33 | 12.04 | 12.03 | 13.13 | 13.20 | 12.86 | 12.15 | 12.00 | 11.90 |
| Number of Sternal, . | 9.88 | 7.88 | 8.14 | 7.96 | 7.09 | 7.18 | 7.54 | 7.28 | 6.92 | 7.6 | 7.1 |
| Number of Floating, . | .44 | .77 | 2.33 | 1.45 | 2.00 | 2.75 | 2.00 | 2.00 | 2.25 | 1.80 | ... |
| Number of 8 True Ribs (per cent.), . | 100 | 66 | 100 | 96 | 17 | 18 | 54 | 28 | 8 | 60 | 10 |

It is extremely interesting to trace the connection which runs through all these groups; and although there are undoubtedly ups and downs, these departures from the main track are most probably simply coincident with the branchings which have taken place from the direct line of descent, brought about by the changes in the environment of the offshoot. It must also be remembered that some of these 'groups' now only contain animals which stand at the top and bottom respectively of what once was a very large genus, so that we should expect to find considerable variability: this is especially so of the Lemuroidæ and Platyrrhini, the latter embracing specimens differing very considerably from each other; indeed, some of these, as far as the arrangement of the ribs go, would appear to have reached a higher grade than those classed as above them—the lowest Catarrhini; and it is interesting, in this respect, to notice the opinion held by several naturalists, that Platyrrhini have originated from a type of Lemuroidæ independently of the old world monkeys.

If a careful comparison of these figures be made, I think it will be admitted that the premises are justified, viz.—

1st, *That a gradual reduction takes place in the total number of ribs.*

This is, indeed, perhaps the most striking feature brought out

by the table, the reduction from 14·1 in the Lemuroideæ to 11·9 in man being singularly constant all along the line, although it is to be noticed that in this, as in many other anatomical respects, the lowest genus of one family appear to start afresh from a somewhat lower grade than that to which the higher species of the family immediately beneath them have attained. This retrograde movement is apparent in the figures given under each variety of rib, and is probably due to several causes. It is not unreasonable to suppose that greater specialisation and adaptation to environment has taken place amongst the higher types of what may be a comparatively lower order; and another thing—the ‘missing links’ are so many—our natural orders are, after all, but convenient conventionalities; and were the missing links found, we should find that the whole of nature was blended imperceptibly together.

It is worth noting that this reduction seems to run not only through Primates, but also throughout the whole of Mammalia, thus:—

| N. O. | No. of Ribs. |
|------------------|---------------------|
| Edentata, . . . | 24 (Sloth). |
| Cetacea, . . . | 15 to 16 generally. |
| Sirenia, . . . | 17 to 20. |
| Ungulata, . . . | 18 to 20. |
| Carnivora, . . . | 14 to 15. |
| Primates, . . . | 13 average. |

In man, it is by no means rare to find that this decrease has proceeded a step further, either in the rudimentary condition of the last pair of ribs, or their actual suppression.

With the relation between this decrease in the number of ribs and rise in the animal scale, we have at present no concern. Professor Struthers thinks that it is brought about in man by the increased movement which takes place in the lumbar region; but it is also likely that, with the greater variety and freedom of movement which is developed in the upper limbs, the shape of the upper part of the chest undergoes a change from compression laterally to one from before backwards, and that consequently the capacity of this part of the chest is increased, and a compensatory reduction takes place below, causing the gradual obliteration of one or more ribs. It is interesting in this connection to note the facts brought forward by G. B.

Howes* of two cases in which an additional lumbar rib was present in the rabbit coincident with functional inefficiency of the upper part of the thorax. Whatever may be the explanation, the fact is none the less striking, and certainly the thorax does widen and expand above as it decreases below, and in the apes the reduction is most marked in oranges and gibbons—the length and freedom of whose arms is noteworthy.

2nd, *A reduction takes place in the number of sternal ribs.*

This is subject to a slightly greater amount of variation, but is nevertheless in evident relation to the first change described, the ratio between true and total ribs being very fairly constant, and as 7 is to 12.

This decrease in sternal ribs and relation to total ones is shown in the accompanying table,—the upper one representing total and the lower true ribs in each case.

TABLE II.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Ribs. | |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|---------------|------------|
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | Lemuroideæ. | } Monkeys. |
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | Platyrrhini. | |
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | Cercopitheci. | |
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | Macaci. | |
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | Semnopitheci. | |
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | Gibbons. | } Apes. |
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | Chimpanzee. | |
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | Gorilla. | |
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | Orang. | |
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | Man (dark). | } Man. |
| _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | Man (light). | |

* *Proceedings of Anatomical Society*, 1892.

3rd, That the 8th rib is usually united to the sternum in man.

This change is exceedingly interesting, and the percentage of 8 true ribs gradually passing smaller and smaller as we approach man. In man there are only occasionally 11 per cent. of cases with 8 true ribs. In apes generally 34 per cent., and the number of cases steadily increases through monkeys until in *Cercopithecus* there are 100 per cent.—always 8 true ribs. And going down still further we get a constantly increasing proportion of 9, 10, 11, and finally 12 sternal ribs.

These changes are shown diagrammatically in figs 1 and 2.

It is readily apparent that the three changes described are interdependent, and owe their existence to—

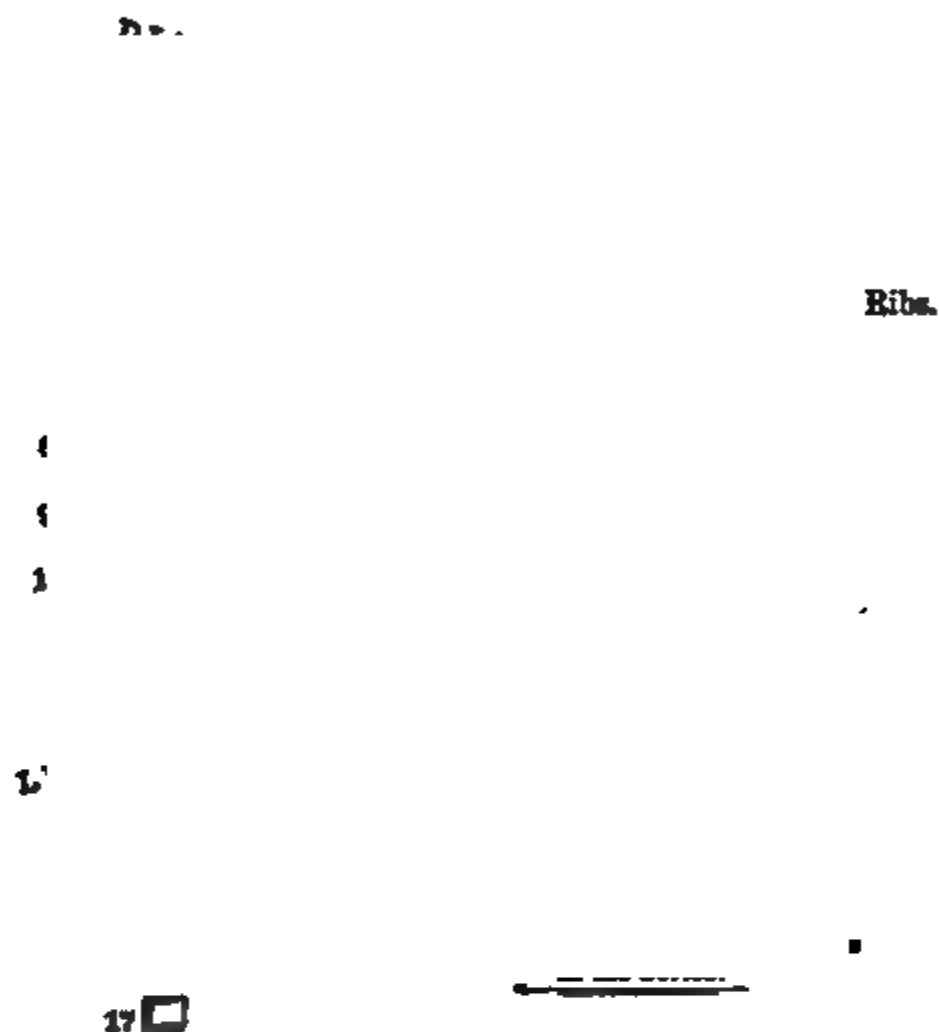
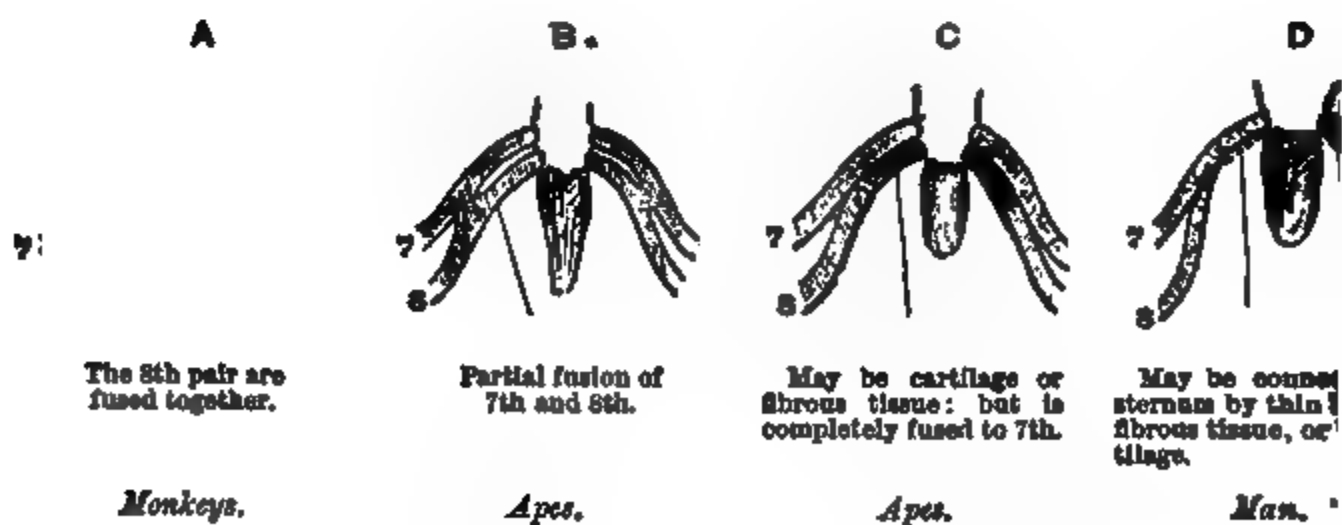
4th, A gradual shortening of the thoracic cavity from below. But this alteration in the thorax is more one of shape than of capacity, the reduction being compensated by increased breadth above: indeed it would seem likely that this increased breadth, brought about by greater variety of movement in the upper limbs, is one of the chief causes of the reduction.

Such are the changes which take place throughout the order: have they any bearing upon the abnormalities which occur in man?

1st, *With regard to the variability of the 8th rib*.—This is seen to be by no means peculiar to man alone: there is a variation in the attachment of the 8th cartilage in every genus of the order but two. In these (*Lemuroideæ* and *Cercopithecus*) there are more than 8 true ribs present, so that the position of this remains constant. Variations, however, occur in the position of the lowest true rib in just the same way; and in the Orang, although there are apparently rarely more than 7 true ribs, the 8th unites with the 7th at a variable distance from the sternum.

Variability with regard to sex.—The statements on this point are somewhat conflicting with regard to man; but I think there can be no doubt that an 8th true rib is more frequently found in the male than female. I cannot find this preference for sex to hold in the apes or monkeys.

Variability with regard to side.—Undoubtedly in the human race cases of an 8th true rib are much more frequent on the right side; but whilst in the male it occurs in the proportion

FIG. 3.—*Mode of Attachment of the Lowest True Rib.*

of R. 11·8 per cent. to L. 8·8 per cent., the preference seems to be still more strongly marked in the female, being R. 6·5 per cent. to L. 0 per cent. In the lower members of the order, although the variability is well marked, it does not seem to exert any preference for side or sex,—perhaps the number of specimens is too small.

The cause of this is not very obvious. Professor D. J. Cunningham * is inclined to think that it is related to the greater use man makes of his right hand, and considers that this has resulted in an *extension* of the 8th right rib to the sternum; but there are several objections to this,—that an 8th true *left* rib is found in a proportion of cases far in excess of left-handed people; in fact, an 8th rib does not occur so very much oftener on the right than left side in the male, although it does in the female.

The preference is unnoticeable in the apes, and they, especially the oranges, are also right-handed; and then this extension of an 8th rib to the sternum would necessarily imply that man or his predecessors originally possessed but 7 ribs, whereas we have seen that a decided increase takes place in the number of true ribs as we go down the animal scale.

Professor Hyrtl attributed it to tight-lacing in the female.

I think that the more probable explanation is this: The change is a progressive one: that man's thorax, in common with that of all the Primates, undergoes that gradual shortening from below; that part of it which is more functionally important is more persistent; that which is less so is more inclined to go first; the ribs, originally protective for dorsal nerve and blood systems in fishes, have become so modified in amphibians, birds, and mammals, as to be secondary structures, almost solely to the lungs, affording them protection, and being one of the chief agents in their expansion. The right lung is of greater functional value than the left, weighing two ounces more, and the reduction of the 8th rib is consequently less apt to occur on that side, owing to the greater need of protection which this increased value requires. The liver is also an important organ needing protection, and probably exerts an influence in this persistence of the 8th right rib to the sternum.

* *Journal of Anat. and Phys.*, vol. xxiv. p. 127.

This reduction of total and true ribs is so uniform all along the series that one would expect to find in pre-historic man a greater percentage of cases of 8 true ribs than at present occur—they are certainly more common in the dark races. Now we occasionally come across but 6 attached to the sternum.

The mode of attachment of this last true rib is also interesting, and follows the same gradual change. First the fusion of the pair across the base of the ensiform, as well shown in *Macaci*; then the central piece goes, and the cartilages of opposite sides are blended with the lower end of the gladiolus and base of ensiform; next the cartilage becomes closely applied to the lower edge of the one above, sometimes indeed being only carried on to the sternum by fibrous tissue, as in higher apes and occasionally in man; and lastly, this intervening piece of cartilage or fibrous tissue goes, and the rib has only a costal attachment. (See fig. 4.)

The abnormalities in the total number of ribs met with in man are either increase or decrease, which may be either above or below; and it may be said that generally the additional rib is above, and the decrease takes place below.

The following table gives the abnormalities found in monkeys and apes. It will be seen that although they are not common in the cervical region, they do occur. In the lumbar region they are much more frequent; and whilst amongst monkeys all the examples I have seen are in *addition* to the ordinary number, in the apes the greater number of cases are of those in which there appears to be a falling off.

This also appears to be the most common variation found in man. It is seldom that the extreme is met with, in which the 12th rib is quite absent; but cases in which the last pair are much shorter than usual are by no means rare. Struthers,* in his paper on rib variations, records no less than 5 instances of this kind,—in one the 12th pair being so small that they might easily have been overlooked; the others ranging from 1 to 2 inches long, all amongst Europeans.

The explanation of these abnormalities in man is probably twofold, and the same holds good of the lower orders. 1st, That

* "Variations of Vertebrae and Ribs in Man," Struthers, *Jour. Anat. and Phys.*, vol. ix.

TABLE III.—*Abnormal Ribs in Monkeys and Apes.*

| | Cervical Region. | Lumbar Region. | | | | |
|-----------------------|--|---|---------|---------|--|------------------|
| | | + Rudimentary Ribs present in excess of the average No. of the genus. | | | - Rudimentary Ribs present—in which the total No. of Ribs remains the same. | |
| Monkeys. 81 cases. | 0 | Lemur. | R. 1 | L. 1 | | R. |
| | | Platy. | 1 | 1 | | L. |
| | | | 1 | 1 | | |
| | | Mac. | 1 | 1 | | |
| | | Semn. | 1 | 1 | | |
| Apes. 52 cases. | 1 Chimpanzee. A rudiment- ary pair about 2½ inches long to contiguous portions of 6 and 7 C.V. The 1st sternal rib to 7 C. and 1 D. | Gibbon. | 1 | 1 | | Absent. |
| | | Chimp. | 1 | 1 | | Normal. |
| | | | 1 | 1 | | |
| | | | | | | Rudy. Absent. |
| | | | | | | Absent. |

additional ribs are due to the persistence of a former condition ; indeed, W. N. Parker states that in the embryo of man cervical and lumbar ribs are actually laid down in common with those of the dorsal region, but subsequently disappear : and 2nd, *that a decrease* is simply a part of that steady progressive change which has been seen to run right through the order. Judging from the relatively greater number of cases of decrease as compared with increase, it would seem that man is still following in the footsteps of his progenitors, and that reduction of the thorax from below is still taking place. Possibly the anatomist of the future will describe the normal number of ribs in man as 11.

My thanks are due to the authorities of the Natural History Museum, South Kensington ; the Royal College of Surgeons of London ; and especially to Dr A. Keith, Senior Demonstrator of Anatomy at the London Hospital, for the opportunity they have afforded me of obtaining the statistics upon which this paper is based.

NOTES ON CERTAIN PHYSICAL AND PHYSIOLOGICAL MEASUREMENTS AND ESTIMATES. By JOHN G. M'KENDRICK, M.D., *Professor of Physiology in the University of Glasgow.*

- 1.—Units {
 - Fractions of an inch.
 - Millimetre = $\frac{1}{25}$ th of an inch.
 - Micron = $\frac{1}{1000}$ of 1 mm. = $\frac{1}{1000}$ of $\frac{1}{25}$ = $\frac{1}{25,000}$ th inch.
 - Micron = μ .
 - 2.—Diameter of a *molecule* from $\frac{1}{2,000,000}$ to $\frac{10}{2,000,000}$ of a millimetre, or $\frac{1}{25,000,000}$ to $\frac{10}{25,000,000}$ of an inch.
Take diameter at $\frac{1}{2,000,000}$ millimetre or $\frac{1}{25,000,000}$ inch.
 - 3.—Suppose each *biophor* (vital unit of Weismann) to be cubical, and to contain 1000 molecules, that is ten in a row, or $10 \times 10 \times 10 = 1000$. Then the *biophor* would measure 10 molecules in length, or $\frac{1}{2,000,000} \times 10 = \frac{10}{2,000,000}$ or $\frac{1}{200,000}$ mm.
 - 4.—200 biophors would therefore measure $\frac{200}{200,000}$ or $\frac{1}{1000}$ millimetre or 1μ , (micron), or the $\frac{1}{25,000}$ of an inch.
 - 5.—Imagine a cube, one side of which was 1μ or $\frac{1}{25,000}$ th inch, it would contain $200 \times 200 \times 200 = 8,000,000$ biophors.
 - 6.—A human red blood corpuscle measures about 7.7μ in diameter and 1.6μ in thickness: suppose it to be cubed it would contain 3,652,000,000 biophors. As it is not a cube but only a disk 1.6μ in thickness, it will contain considerably fewer. If we take it as a disk of uniform thickness (1.6μ) and not biconcave, as it really is, the number of biophors would be 416,000,000.
 - 7.—Smallest particle of matter that can be seen with highest microscopic powers is $\frac{1}{25,000}$ millimetre or $\frac{1}{250,000}$ th of an inch.
 - 8.—Each biophor is $\frac{1}{200,000}$ mm. in diameter, so there would be 10 in the $\frac{1}{25,000}$ millimetre, or 1000 in the *cube*.
-
- 9.—Average diameter of molecule = $\frac{1}{2,000,000}$ mm.
 - 10.—Smallest visible particle = $\frac{1}{25,000}$ mm. Then there would be in the side of the cube, in a row 100 such molecules, or in the cube $100 \times 100 \times 100 = 1,000,000$ molecules.
 - 11.—A *molecule* of organised matter contains about 50 elementary *atoms*. So that the 1,000,000 molecules in groups of about 50 would number $\frac{1,000,000}{50} = 20,000$ organic particles.
 - 12.—Thus a cube $\frac{1}{25,000}$ mm. would contain about 20,000 organic particles.
 - 13.—Suppose one-half to be water, then there would remain 10,000 organic particles. That is 22 in a row. Each would then be about $\frac{1}{440,000}$ mm.

14.—The organic *molecule* must be 5 times larger at least than a molecule of H.

| | |
|-----------------------|--------------------------|
| <i>Molecule of H.</i> | <i>Organic Molecule.</i> |
|-----------------------|--------------------------|

| | |
|---------------------------|-------------------------|
| $\frac{1}{2,000,000}$ mm. | $\frac{1}{440,000}$ mm. |
|---------------------------|-------------------------|

15.—Smallest visible cube would contain in a row
100 molecules of H. and about 22 molecules of organised matter.

16.—Now as 200 biophors = $1\mu = \frac{1}{1000}$ mm.

Then 1 biophor = $\frac{1}{200,000}$ mm. in diameter.

17.—That is to say the smallest particle of matter visible to the highest microscopic powers,

$\frac{1}{20,000}$ mm.—is $\left\{ \begin{array}{l} 10 \text{ times the diameter or} \\ 1000 \text{ times the volume} \end{array} \right\}$ of the ultimate vital unit—the biophor = $\frac{1}{200,000}$ mm.

18.—Diameter of a molecule of H = $\frac{1}{20,000,000}$ inch, or $\frac{1}{2,000,000}$ mm.

19.—Smallest *particle* that can be seen microscopically is $\frac{1}{200,000}$ inch, or $\frac{1}{20,000}$ mm.

20.—Smallest ultimate vital unit (biophor)
is $\frac{1}{2,000,000}$ inch, or $\frac{1}{200,000}$ mm.

21.—Smallest particle (visible cube) that can be microscopically seen may contain 20,000 organic particles + water.

22.—Smallest ultimate vital unit (biophor) may contain 20 organic particles.

23.—Germinal vesicle is about $\frac{1}{800}$ inch in diameter—or $\frac{1}{20}$ th mm.

24.—Germinal vesicle may contain 1,000,000,000,000 biophors.

25.—Head of sperm cell is about $\frac{1}{8000}$ inch in diameter, or $\frac{1}{200}$ mm.

26.—Sperm cell element may contain 1,000,000,000 biophors.

27.—Smallest thing that can be seen with naked eye, $\frac{1}{800}$ inch, or $\frac{1}{24}$ of a mm. *The retinal image at distance of 1 inch from eye would be $\frac{1}{12,800}$ inch, or about 4 wave-lengths of light.*

28.—Germinal vesicle is $\frac{1}{800}$ inch, or $\frac{1}{20}$ of a mm.

29.—Sperm cell is $\frac{1}{8000}$ inch, or $\frac{1}{200}$ of a mm.

30.—Wave-length of green light is $\frac{1}{20,000}$ inch, or $\frac{1}{2000}$ of a mm.

31.—Smallest thing that can be seen with microscope is $\frac{1}{200,000}$ inch, or $\frac{1}{20,000}$ of a mm., or $\frac{1}{10}$ th of a wave-length of light.

32.—Ultimate vital unit (biophor) is $\frac{1}{2,000,000}$ inch, or $\frac{1}{200,000}$ of a mm., or $\frac{1}{100}$ th of a wave-length of light.

33.—Molecule of organised matter, like albumen, is $\frac{1}{440,000}$ mm., or $\frac{1}{11,000,000}$ inch.

34.—Molecule of hydrogen is $\frac{1}{20,000,000}$ inch, $\frac{1}{2,000,000}$ of a mm., or $\frac{1}{1000}$ th of a wave-length of light.

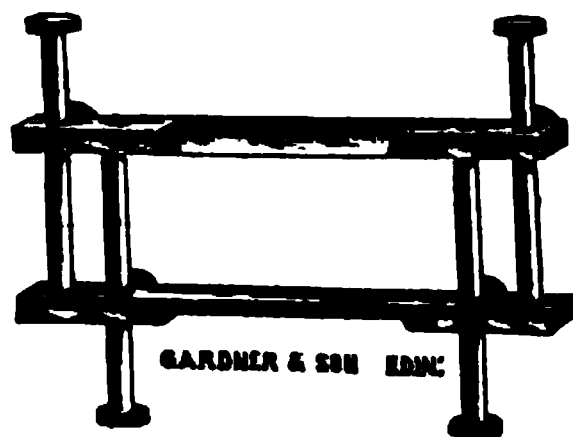
35.—Average wave-length of light, $\frac{1}{20,000}$ inch.

- 36.—Velocity of light in round numbers :—186,000 miles per second ; there are about 62,208 inches per mile ; $186,000 \times 62,208 = 11,570,680,000$ inches per second. $11,570,680,000 \div 1/50,000 = 11,570,680,000 \times 50,000 = 578,534,000,000,000$ vibr. per second falling on retina.
- 37.—Diameter of a single retinal rod or cone is about $\frac{1}{8000}$ th inch.
- 38.—Length of shortest vibrating hair in the ear, $\frac{1}{1400}$ inch. Diameter about $\frac{1}{4}$ of $\frac{1}{1400} = \frac{1}{5600}$ inch.
- 39.—Rod or cone = $\frac{1}{8000}$ inch, or $\frac{1}{320}$ mm. Suppose a cube. It might contain 240,000,000 biophors. As the rod or cone is prismatic or cylindrical in shape, the number of biophors—bodies possibly differing as to sensitiveness to light—may be two or three times greater. Groups of such elements of the rod or cone may be differently affected by various wave-lengths.

NOTE ON TWO USEFUL ACCESSORIES IN SERIAL SECTION-CUTTING BY THE PARAFFIN METHOD.¹

By THOMAS H. BRYCE, M.A., M.B. Glasgow.

THERE is no doubt that, for celerity and success in serial section-cutting, the fundamental necessity is to get a straight ribbon. It is not altogether easy, with an ordinary knife or razor, to make the sides of the block so mathematically parallel and even, as to ensure this



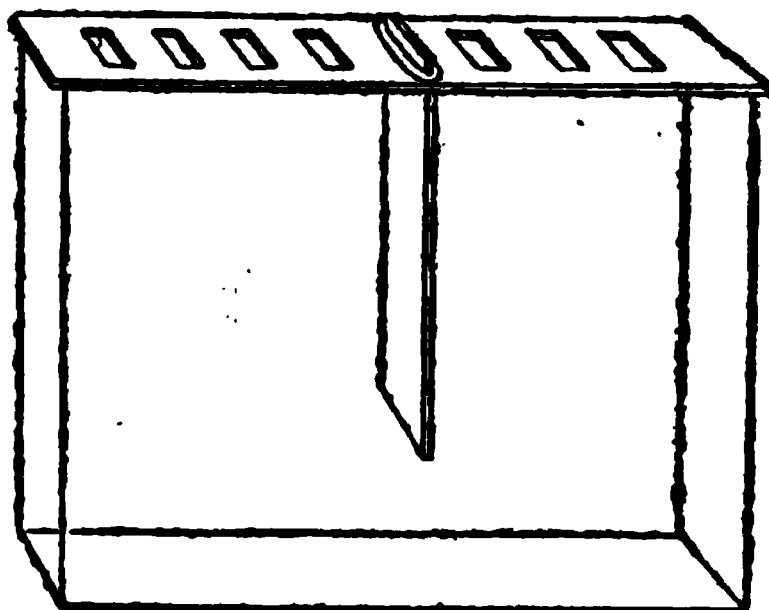
result. The problem is met in the Minot microtome ; but among the large number of workers who use the Cambridge Rocker there may be some who have experienced my difficulty, and to those I believe the parallel-bladed knife figured here may prove helpful, and economical of time.

The instrument has two blades, chisel-edged, with the straight edge inwards. Each is provided with two bars, running in slots in the opposite blade. The blades are thus kept perfectly parallel, and they can be adjusted to any required distance. They are quite rigid, but screws are provided for clamping them in any required position if necessary. The paraffin block is roughly cut out with a sharp knife, and then a few seconds will suffice, either before or after the block is

¹ Read at meeting of the Edinburgh Pathological Club, November 25, 1896.

mounted, to pare it down into mathematical exactness. The instrument is made by Mr Gardner, instrument-maker, Edinburgh.

After the ribbon is fixed in series on the slides, the great desideratum is a saving of time in putting them through the different processes for removal of the paraffin, &c. The vessel figured here has proved so serviceable to me, and economical both in time and reagents, that I am induced to direct to it the attention of those who may be looking



for something of the kind. The idea was suggested by Caro,¹ but the vessel has not yet been put into the English market. As made for me by Messrs Baird & Tatlock, it is a narrow glass trough, deep enough to hold a slide. It is provided with a vulcanite cover, in which there is a series of slits, each long enough to admit a slide, and broad enough to allow it to be lifted out without danger of rubbing the sections off. A rubber ring is placed round the one end of the slide, and this suspends it in the fluid. A whole series can thus be carried through the various processes at one time, by lifting the cover, with its slides, from trough to trough. When not in use, a glass cover keeps out dust and prevents evaporation.

SUMMARY OF A PAPER ENTITLED—"ON THE VARIATIONS IN THE CHARACTER OF THE CONTRACTIONS OF STRIATED MUSCLE WITH PERIODIC STIMULATION OF SOME DURATION, AND ON RECOVERY OF THE MUSCLE."² By ALEXANDER ROLLET, *Professor of Physiology in the University of Graz.*

(Reported by David Fraser Harris, M.B., Physiological Department, University of Glasgow.)

1. In fresh muscles, capable of contracting, there is stored up a quantity of disassimilable substance.

¹ *Zeitschrift für Wissenschaft. Mikroskopie, &c.*, B. 12, Heft 1, p. 18.

² *Archiv. für die ges. Physiologie*, Bd. 64, p. 507.

2. This store may be greater or less.
3. Through the activity of the muscle it becomes less, and can be used up to a known extent.
4. By this disassimilation are produced a number of different evanescent katabolic products.
5. These are present in varying amount, but accumulate up to a limit which can be ascertained.
6. During disassimilation, metabolic products are being produced with greater or less rapidity, and they are not removed from the muscle at all times in the same manner or with the same completeness as at other times. The removal of the katabolic products may be of such a character that after the cessation of disassimilation, its products are again removed from the muscle more or less completely.
7. The removal of the katabolic products may be delayed or may be insufficiently performed, so that during and after the disassimilation there is always a considerable quantity of accumulated katabolic products, which after the cessation of disassimilation are at once gradually removed.
8. There occurs, to a certain fixed extent, the formation (anabolism) of a disassimilable substance, by means of which the substance already katabolised is replaced.
9. Such anabolism proceeds simultaneously with katabolism, and in such a way that the muscle, by the simultaneous removal of katabolic products, is not essentially altered in respect of its chemical constitution.
10. Anabolism continues after katabolism has ceased; the store of disassimilable substance diminishes during katabolism, and is replaced by anabolism continuing after katabolism has ceased.
11. In order to this building up of the store of disassimilable substance by anabolism, a longer or shorter time is necessary after katabolism has done its work.
12. The degree and extent of the new katabolism depends upon the amount of disassimilable substance remaining over in the muscle after the previous period of katabolism, and upon the degree of completeness of removal of the previous katabolic products.
13. If we now suppose a store of disassimilable substance as the source of activity of muscle, and katabolism as the condition of its activity, we are then confined to the choice of one of two ways in which a muscle is capable of acting. These are:—
14. (1) A muscle may be supposed capable of activity by possessing a considerable store of disassimilable substance, seeing that there is such a speedy accumulation, and so slow a removal, of katabolic products; or,
15. (2) A muscle may be supposed to be capable of activity in virtue of a quantity of disassimilable substance which it possesses, and has not entirely exhausted in previous katabolism.
16. The repair of muscle through the removal of katabolic products, and in virtue of a sufficient store of disassimilable substance still remaining over, must be viewed in quite another light from the

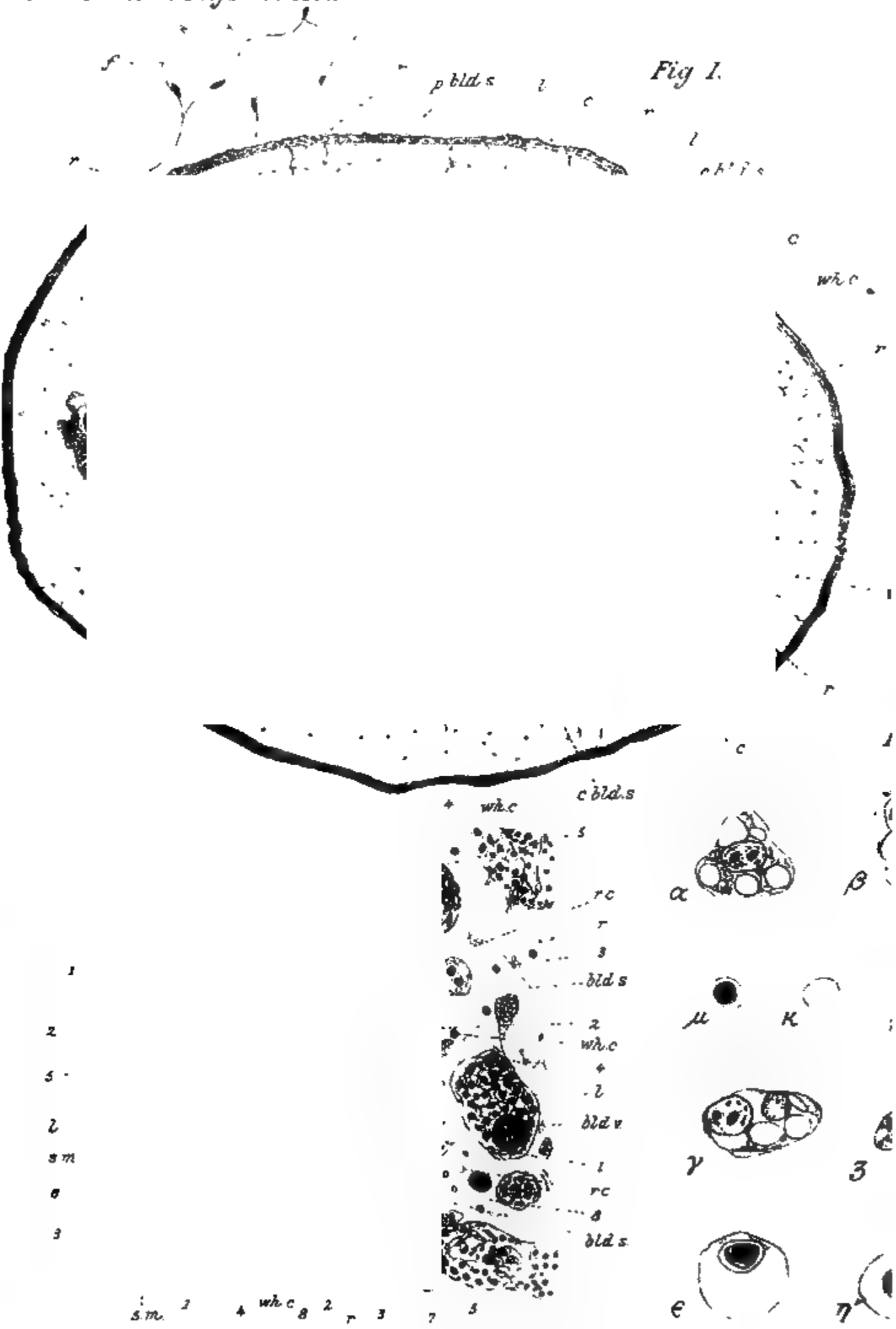
reconstitution of the activity of muscle through the manufacture of new disassimilable substance in place of that previously katabolised.

17. Anabolism might or might not proceed simultaneously with the former variety of the repair of muscle, which repair can only be traced back to the removal of products of katabolism.

18. In the case of the repair of muscle by the anabolism of fresh disassimilable substance, if repair takes place exclusively by means of such anabolism, all katabolic products would be removed long before anabolism was completed.

19. This anabolism would vary in character with the conditions under which it was effected: it would proceed actively enough in the case where there was plenty assimilable substance ready to be anabolised, but it might be delayed or be insufficient in the case where there was a deficiency of such material to elaborate.

The paper concludes:—Katabolism must certainly be regarded as *the* essential chemical condition of muscular activity, the only questionable point being in what way the amplitude and form of the contractions are influenced by factors which themselves modify the process of katabolism. The question also remains, what are the limits to the extent or degree of katabolism; what determines the critical point or points of the flying asunder of the unstable elements of the disassimilable substance; and finally, are there any factors, and if so, of what nature, which exert an inhibitory or augmentative influence upon the process of katabolism itself.



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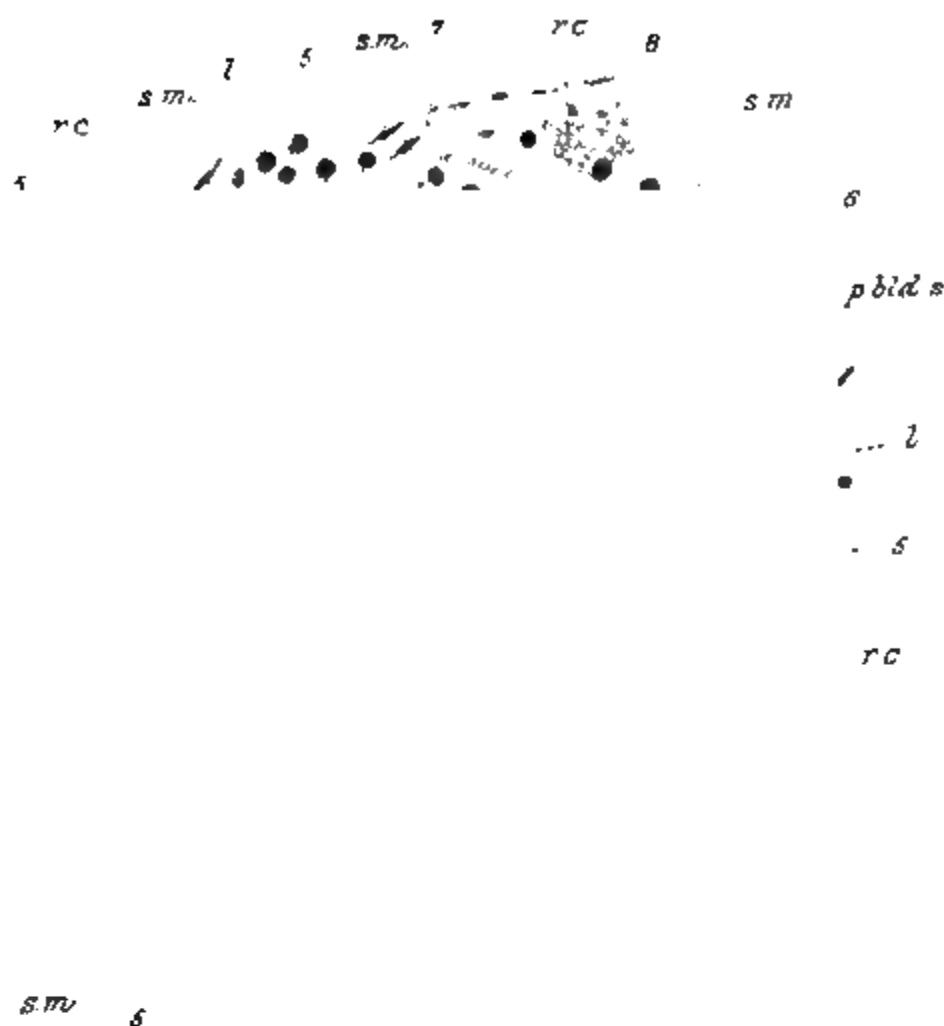
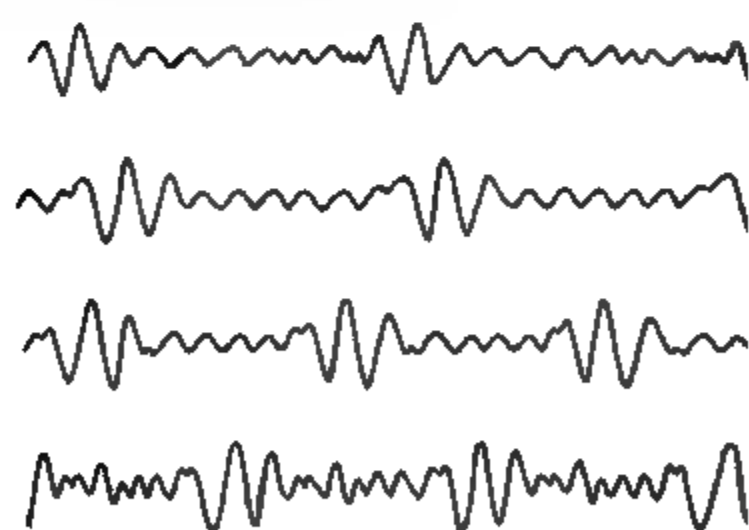
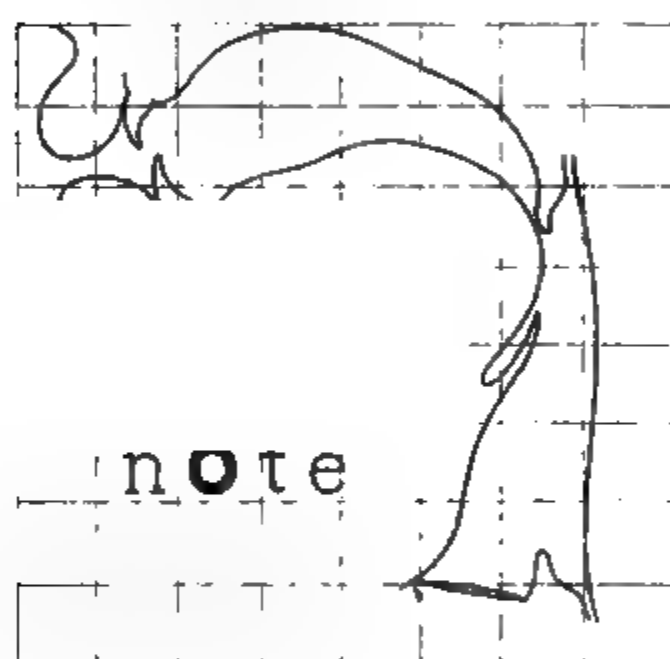
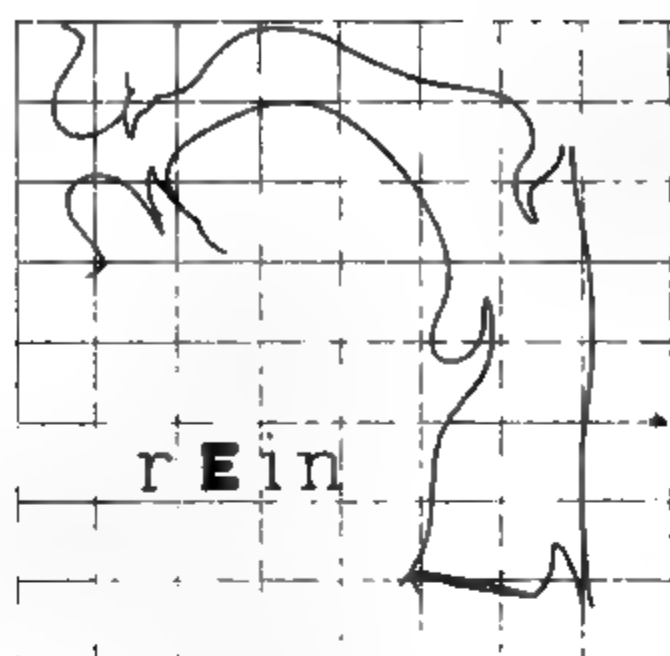


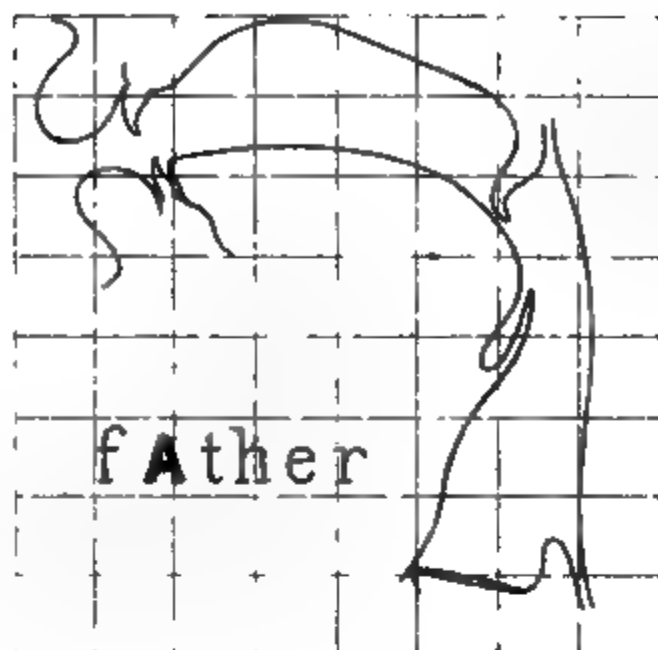
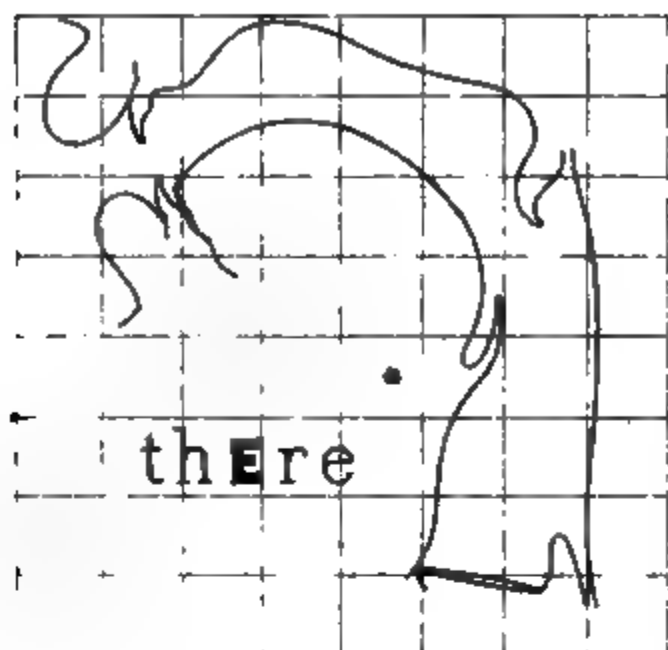
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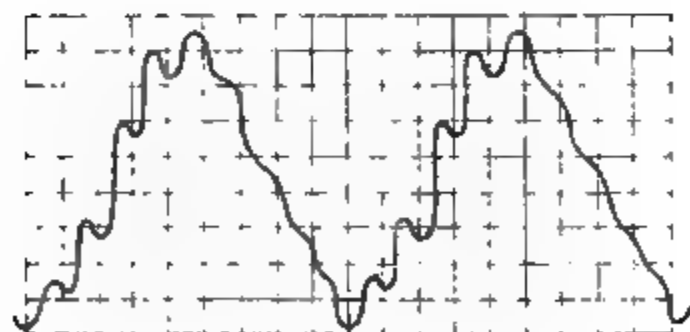
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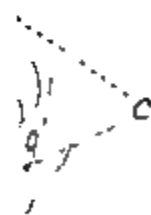
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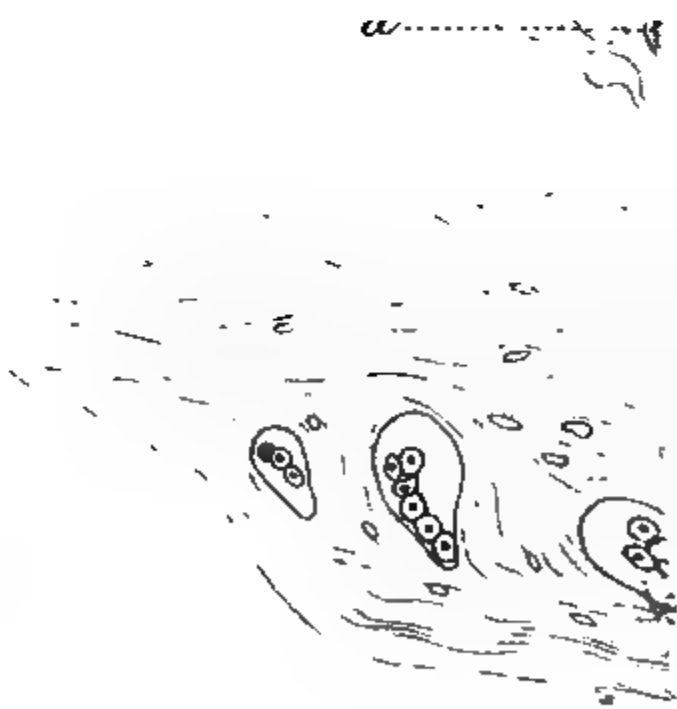


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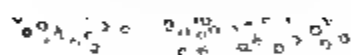


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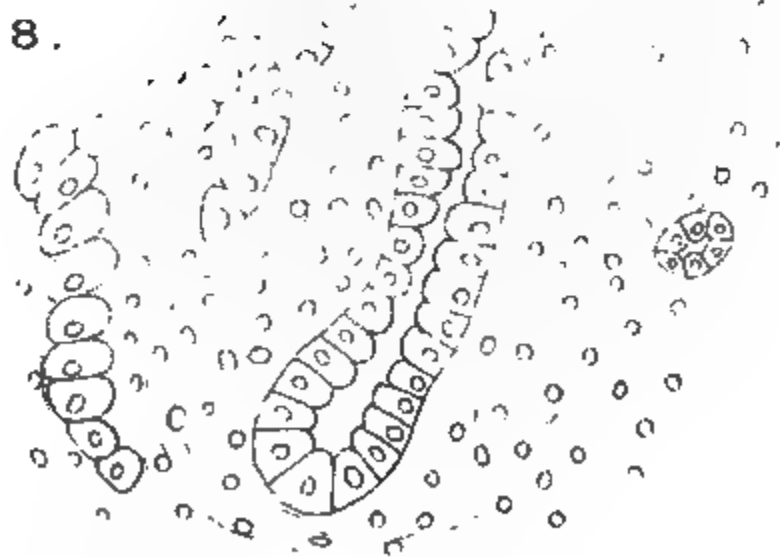
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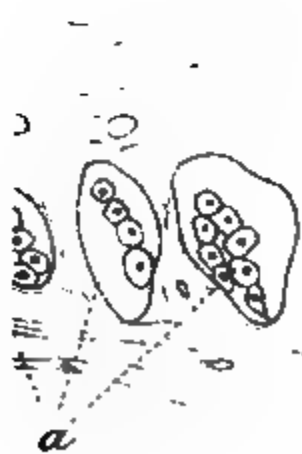
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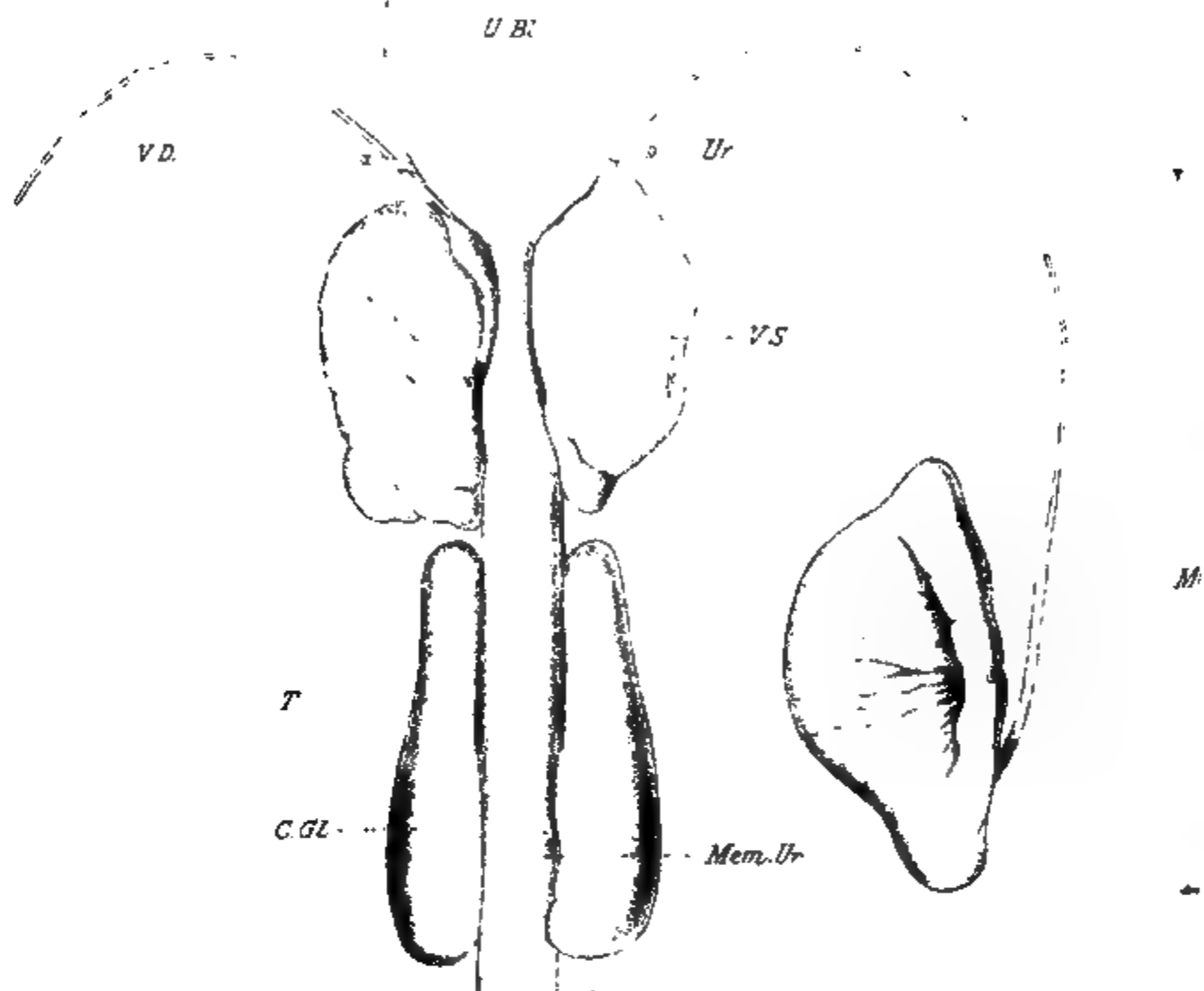


Fig 5

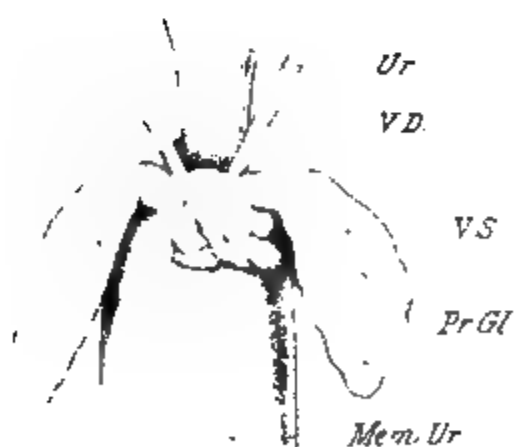
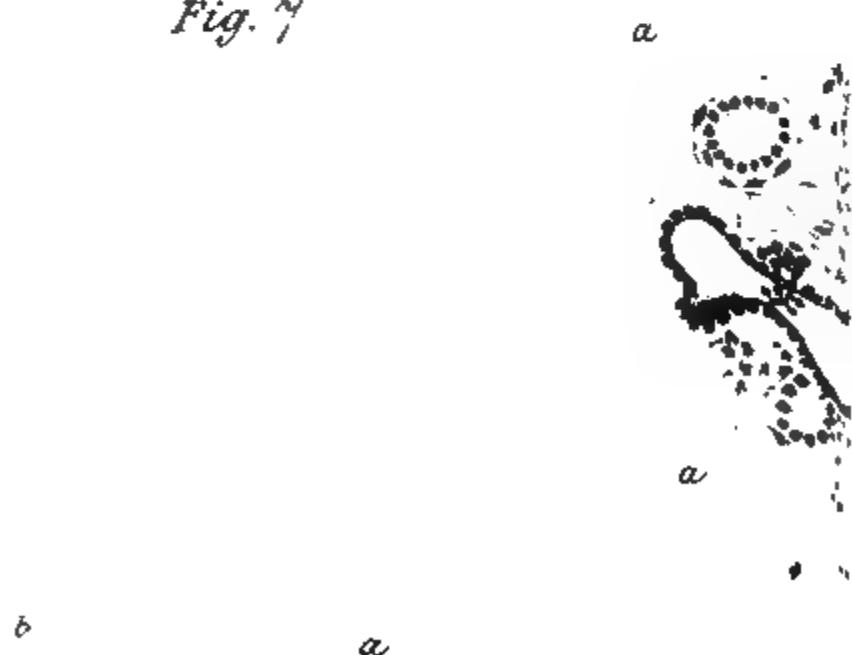


Fig. 7



GENITAL ORGANS,

Journal of Anatomy and Physiology.

ON THE STRUCTURE AND CONTRACTION OF STRIPED MUSCULAR FIBRE. By PROFESSOR RUTHERFORD, M.D., F.R.S. (PLATES XII., XIII., XIV.)

I DEDICATE THIS COMMUNICATION TO
W. MURRAY DOBIE, M.D. EDIN., CHESTER,
WHO WAS AN ACUTE OBSERVER AND CRITIC
OF THE APPEARANCES OF STRIPED MUSCULAR FIBRE
FIFTY YEARS AGO.

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INTRODUCTORY.

IN a paper on the “Minute Structure of Voluntary Muscular Fibre,” read before the Royal Medical Society of Edinburgh in 1848, W. Murray Dobie (ref. 2) thus expressed himself:—
“There is perhaps no animal texture as to the nature of which more contrary opinions have been held, or more conflicting statements advanced, than that of voluntary muscle, so that even at the present time it must still be considered a question by no means set at rest.” Dobie wrote these words eight years

after Bowman (ref. 1) had published his celebrated paper; yet, notwithstanding the lapse of fifty more years, during which microscopical research has been pursued with great activity, aided by greatly improved lenses, and refined methods of histological inquiry, Dobie's words are as applicable now as then.

The difficulties so perplexing to histologists have mainly arisen from the following characters of the tissue. 1. The contractile elements of the fibre are very delicate soft fibrils, that cannot be rightly studied with the microscope unless fixed by suitable reagents, to permit of their separation without distortion in small bundles and as single fibrils, and unless they are suitably stained to permit accurate recognition of their visible structure. 2. The appearances of the fibrils in states of relaxation and contraction are so different, and so difficult to investigate unless the above conditions are fulfilled, that their interpretation has baffled some of the most eminent histologists. 3. The optical effects of curvature are superadded to those of structure, and have greatly misled some observers. 4. Certain parts of the sarcous substance are doubly—others singly—refractile, and this has been a source of confusion to those who have hoped to make reliable observations by examining thick strata of fibrils. 5. The finest structure of the fibrils is beyond the reach of the microscope, so that the secret of contraction will ever remain hidden.

Like most other observers, I experienced for many years much difficulty in knowing what to teach regarding the minute structure of striped muscle. For a considerable time I simply followed Kölliker and others who regarded the primitive fibrils as the essential elements of the sarcous substance. I was for a short period shaken in my teaching by the appearance of Schäfer's paper on the leg muscle of the water-beetle (ref. 30), in which the very existence of Bowman's sarcous elements was ignored, and certain illusory appearances were dignified by the misleading term of "muscle-rods," to which remarkable optical effects were ascribed in the relaxed and contracted states of the fibre. In consequence of that communication I examined the leg muscle of the water-beetle (*Dytiscus marginalis*) in a living state in its own juice, and also in one

per cent. watery solution of sodium salicylate. The excised muscle being free to retract, necessarily showed the characters of the unextended muscle,—the dim stripes being much broader than the light stripes. The excised fibre shows at first no longitudinal striation, but after a little time, apparently owing to some internal change in the sarcous matter, fine dim longitudinal lines appear at regular intervals marking the outlines of the fibrils (fig. 1). Those lines are most evident in the broad dim stripe, but are certainly also continued through the light stripe. The middle of the light stripe is crossed by the well known thin dim stripe, which with proper focussing is seen to consist of a transverse row of globular particles, one in the course of each fibril, and not situated in the course of the fibrillar outlines, as erroneously represented by some observers. Dobie, in the paper already referred to, stated that the thin dim line in question was first seen by Lealand the optician in preparations of pig's muscle; but Dobie searched for it in the muscle of several other animals, and found that when invisible it may frequently be revealed by stretching the muscle. Dobie's description of muscle, although written when he was only an undergraduate, displays so much acute observation and reliable criticism that I have long been in the habit of naming the stripe in question *Dobie's line*, a term short and convenient, and implying no theory. Since Krause (ref. 12) in 1865 directed special attention to the above stripe, and described it as the optical expression of a thin membrane extending at regular intervals across the fibre, it has been frequently designated *Krause's membrane*, a term best avoided, since it implies a theory as to the nature of the line.

The *sarcous elements* of Bowman, of which the broad dim stripe mainly consists, may be more fitly named *Bowman's elements*, to commemorate their discovery by that eminent observer. I have long used that term, which is devoid of the

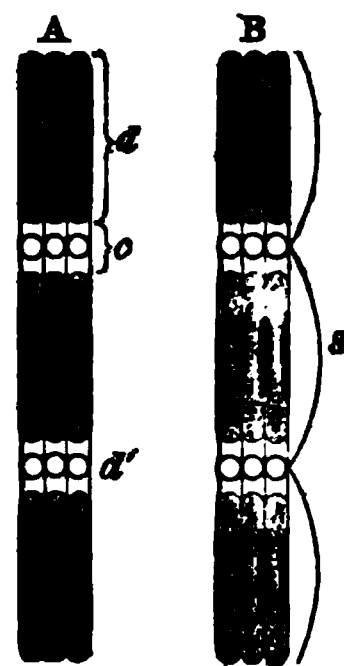


Fig. 1.—A. Portion of a fresh striped muscular fibre from the leg of *Dytiscus* before revelation of the fibrillar outlines. *d*. Dim stripe. *c*. Light stripe. *d'*. Dobie's line. B.—The same after treatment with half per cent osmic acid. *s*. Sarcolemma attached to Dobie lines and swollen up at intervals by imbibition. $\times 1200$.

ambiguity that necessarily pertains to the term *sarcous elements*, seeing that they are not the only structural elements of the sarcous substance. In the fresh muscle of *Dytiscus* their true outlines cannot be defined; but if the muscle be placed for some hours in half per cent. solution of osmic acid they are seen to be rod-shaped bodies with slender shafts, thinner in the middle than at their ends (fig. 1, B), with a clear interstitial substance filling the spaces around the concavities of the shafts, and giving rise to the appearance of slender ellipses between adjacent elements. When I first made these observations in 1879, I became convinced that Schäfer's drawing of *Dytiscus* muscle (ref. 30, pl. xxxiii. fig. 1) is entirely misleading; inasmuch as he has not shown the globules of Dobie's line, but in their place he has figured a narrow continuous light stripe, with a row of minute dim dots on each side of it, which, in my opinion, are mainly due to the doubled shadows of the adjacent globules of Dobie's line. These are necessarily in the course of the fibrillar outlines which Schäfer regarded as the shafts of his so-called "muscle rods." It need surprise no one that an observer should fall into some error in beginning the study of muscle, but it is surprising to find an experienced histologist repeating the above drawing in 1891 (ref. 32), as if he still considered it of value notwithstanding the drawings of the globules of Dobie's line given by Engelmann in 1878, Merkel in 1881, and Rollett in 1885.

I attempted to study the process of contraction in *Dytiscus* muscle by examining entire fibres, but, like all observers who have adopted that uncertain method, I failed to arrive at reliable conclusions, and became convinced that contraction cannot be advantageously studied unless the sarcous substance is fixed by suitable reagents, to permit isolation of the primitive fibrils, and of their separation in pairs or in other small groups without suffering distortion. Merkel arrived at the same conclusion; and it is remarkable that Rollett, who has worked at muscle more extensively than any other observer, should, even in his latest paper (1891), have published what appear to me very misleading representations of the phenomena of contraction in his drawings of entire fibres (ref. 26, pl. i. fig. 4).

I turned from the muscle of beetles to that of the crab in

1880, and I have found it the best of all muscles, both for the teacher and the student of histology, not only because of the comparatively large size of the structural elements of the fibrils, but more especially because crab's muscles are sufficiently large for easy preparation in conditions of relaxation and contraction by the methods to be detailed. At the International Medical Congress held in London in 1881, I was called upon to open a discussion on "The Microscopical Appearances of Striped Muscle during Rest and Contraction" (ref. 27). On that occasion I showed the preparations of crab's muscle from which figs. 13-18 in Plate XII. had been previously copied by my pupil R. J. Harvey Gibson.¹ These drawings reproduced as class diagrams were shown at the Congress, and have since then been used in my teaching. From the same preparations the photographs shown in Pl. XIII. figs. 2, 3, 4, and Pl. XIV. figs 5, 6, 7, were afterwards (1890) taken by the late Mr Adolf Schulze, and were shown by me at the meeting of the British Association in Oxford in 1894, and at the Physiological Congress in Berne in 1895. A brief abstract of my description of muscle given in 1881 was published at the time (ref. 27); and surprise has been expressed that I have not, long ere this, published a detailed account of observations that had led me to conclusions differing widely from those arrived at by Krause, Schäfer, Engelmann, and Klein, all of whose views on muscle were receiving support at that time. But I have found it advantageous to thoroughly mature my observations before publishing this paper, for they have enabled me to understand the subject more fully than I did in 1881. Since that time elaborate papers on muscle have been published by Rollett (refs. 23, 24, 25, 26), van Gehuchten (refs. 7, 8), Retzius (ref. 22), Schäfer (refs. 31, 32), and others, but these authors have left ample room for this communication, which, when compared with some of their writings, will justify my quotation of the words used by Dobie in 1848 as still applicable.

¹ Professor of Botany in University College, Liverpool.

Fig

Fig. 1

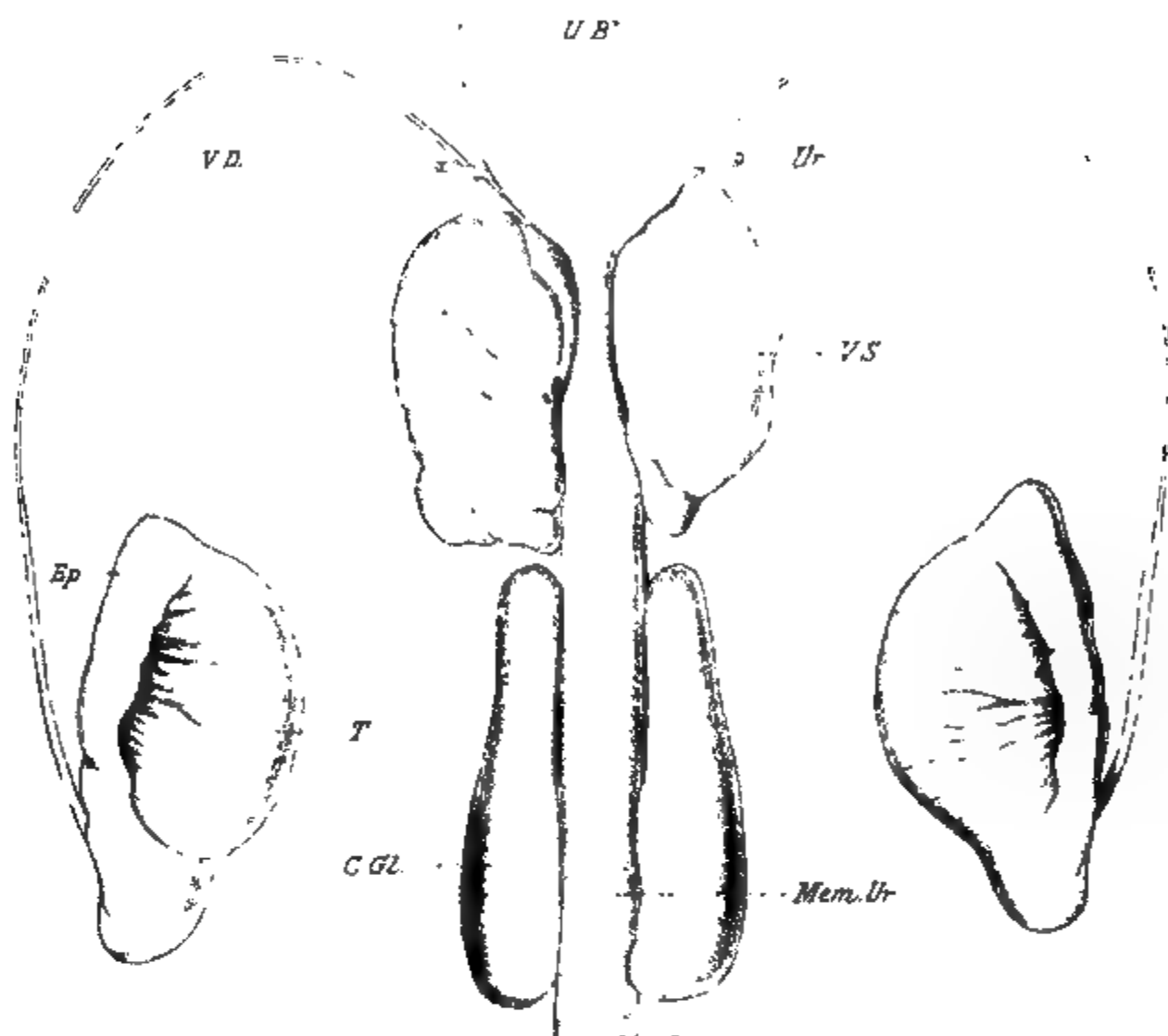


Fig. 5.

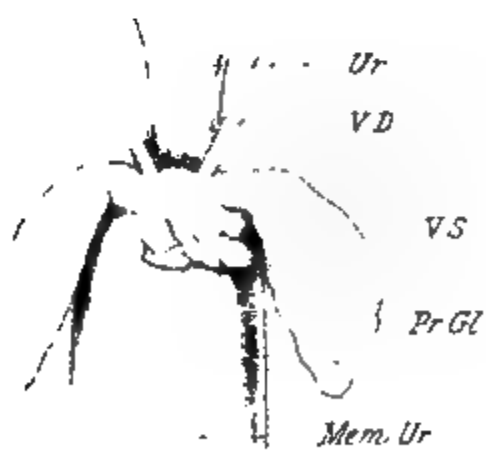


Fig. 7



b

a

GENITAL ORGANS

a 2.

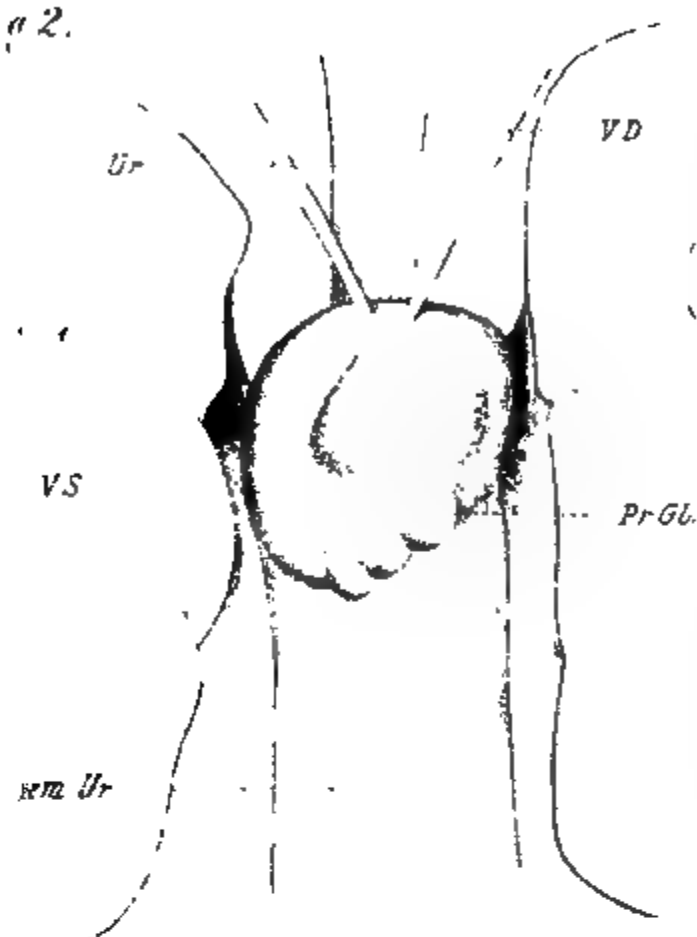


Fig. 6



Const Ur

Muc. Memb.

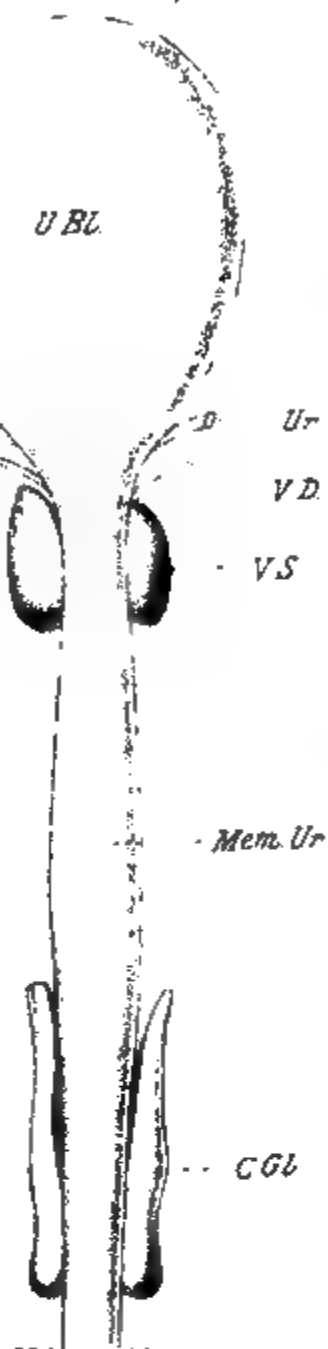
Fig. 3



Const. Ur

Muc Memb.

Fig. 4.



a

b

c

F. Huth, Lith. Edin.

IN BOAR AND PIG.

Heliochine (or *heleosine*?) is a stain more valuable than eosine, for although less transparent, it produces sharper effects. A watery solution rapidly gives a soft red tint to muscle fixed in alcohol, Müller and spirit, or formol. It is perhaps the best stain for formol muscle. It is permanent in glycerine, and shows well in balsam (Pl. XII. figs. 2, 3, 4). When the muscle has been fixed in formol, beautiful preparations may be made by teasing the fibres somewhat; adding glacial acetic acid, then teasing more finely; washing rapidly in water; staining for a few minutes with heliocine; washing in water again, and then mounting in glycerine or balsam. As previously stated, the only effect of acetic acid, even the glacial acid, on muscle fixed in formol, is to render bundles of fibrils somewhat clearer; there is no swelling of the fibrils; the acid appears to brighten and more perfectly fix the heliocine stain. It is to be noted that heliocine fails to stain if from any cause the tissue has been rendered alkaline.

Basic and Acid Fuchsin are also good stains for muscle, although they have no advantage over heliocine, and are not so permanent. A saturated solution of either dye in distilled water is used; the teased muscle left in it 3–24 hours, then washed in water, differentiated in alcohol, and mounted in glycerine or balsam.

Methyl-Blue and Eosine.—The solution of these dyes devised by Gustav Mann gives excellent results with striped muscle. It is made as follows:—

| | | |
|--|-----------|----------|
| 1 p.c. watery solution of Methyl-blue insoluble in absolute alcohol (Grübler), | | 35 c.c. |
| 1 p.c. watery solution of eosine (Grübler), | | 45 c.c. |
| Distilled water, | | 100 c.c. |

(1) Muscle fixed with formol is kept for some days in methylated spirit; (2) teased in absolute alcohol; (3) soaked two minutes in glacial acetic acid; (4) stained in heliocine solution for one minute by allowing drops of the heliocine solution to wash away the acid; (5) transferred to methyl-blue eosine stain for $1\frac{1}{2}$ –2 minutes; (6) carefully washed with distilled water; (7) dehydrated with absolute alcohol, and teased further if necessary; (8) cleared in Bergamotte oil, and (9) mounted in Bergamotte balsam.

All the above agents stain the chromatin of Bowman's elements, the globules of Dobie's line, and Flögel's elements. *Osmic acid* darkens the chromatin. A good method is to inject $\frac{1}{2}$ p.c. solution through a joint into the proximal segment of a living leg; then to open the leg and wash the muscle in water. *Gold chloride* has been overrated as a staining agent for muscle. Its action is capricious and uncertain. It may stain the chromatin in the fibrillar segments, but shows nothing that is not more easily and more clearly revealed by other methods; or it may stain the interfibrillar substance or the outlines of fibrillar bundles, and produce such appearances as those shown in Pl. XII. fig. 23, which will be referred to later on. The appearances in the above fig. were obtained by the method used by Melland (ref. 14). I have also used the methods recommended by Ciaccio and by Rollett.

MUSCLE OF CRAB.

UNCONTRACTED.

The contractile elements in the sarcoous substance of a striped fibre consist of exceedingly fine fibrils arranged in longitudinal bundles. A noncontractile substance, termed *sarcoplasma* by Rollett, fills up the intervals between the bundles, surrounds each fibril within the bundles, and also surrounds the nuclei beneath the sarcolemma. The contents enclosed by the sarcolemma are therefore contractile fibrils, sarcoplasma, nuclei, and in addition to these the terminals of nerves. It is customary with some histologists to describe the sarcoous matter as if it consisted of discs; but such mode of description only leads to confusion; therefore, I shall first describe a single fibril; and although my nomenclature is novel, I trust that in the end its simplicity and convenience may become apparent.

MUSCLE EXTENDED TO ITS FULL PHYSIOLOGICAL LENGTH.—A single fibril of the flexor muscle of the crab's pincer claw extended to its full physiological length, when suitably fixed and stained, is seen to consist of a linear series of alternate segments, which I regard as three in number.

1. *Bowman's Element* is a somewhat dim, slender cylinder, slightly rounded at its ends and thinnest in the middle third or so of its shaft (Pl. XII. fig. 1, A, b). Its protoplasm is bounded laterally by an envelope too thin to be visible, but whose existence must be inferred from the shape assumed by the element when it swells after the addition of acetic acid (fig. 6, A, b). It must also be inferred that there is a node at the equator of the element by which it is virtually divided into two halves, although there is no evidence of any transverse membrane such as Merkel described (ref. 16). The dimness of the element arises from a substance which is readily stained by various dyes, and may therefore be termed *muscle chromatin*: it being understood that the term implies no theory as to its chemical nature, which is quite unknown as yet. But it may here be stated that when subjected to Lilienfeld and Monti's test with ammonium molybdate, it is proved to contain phos-

phorus; and further, that it resembles fats in the readiness with which it is stained by osmic acid. During contraction the chromatin shifts its place from the shaft to the ends of Bowman's element, causing them to swell out, and leaving the shaft clear (Pl. XII. fig. 1, E, F, *b*). The average length of Bowman's element in crab's muscle extended to its full physiological length is $10\ \mu$, and its greatest breadth is $0.86\ \mu$.

2. *The Intermediate Segment*.—It is convenient to apply this term to the cylindrical segment placed midway between the ends of Bowman's elements (Pl. XII. fig. 1, A, *i*). Its average length is $6\ \mu$, rather more than half the length of Bowman's element. At its equator, there is a node whose position is marked by a spheroid which may be fitly termed *Dobie's element*, since it gives rise to Dobie's line when the fibrils are in lateral apposition (fig. 1) (Pl. XII. fig. 3). Dobie's element is tripartite, and consists of a thin transverse band at its equator (Pl. XII. fig. 1, A, B, *n*), and a hemisphere of chromatin on each side of it (*a, a*). I propose to term the transverse line the *intermediate nodal line*. In muscle fixed with formol, it is clearly revealed by staining with heliocine or methyl-blue eosine: it stains more deeply than the ordinary chromatin adjacent to it. I failed to see the tripartite nature of the spheroid in question, until I adopted formol as a fixing agent; and I was fully convinced of the above facts by stretching fibrils imperfectly fixed by picric acid and corrosive sublimate, and finding that the hemispheres of chromatin could be pulled away from the nodal line, leaving it clearly revealed when deeply stained. The chromatin of Dobie's element does not shift its place during the contraction of the fibril.

Flögel's Element.—I have been in the habit of applying this term to a delicate pear-shaped particle containing or consisting of chromatin, placed in each half of the shaft of the intermediate segment (Pl. XII. fig. 1, A, *f*). I believe the particle was first seen by Brücke, but my attention was first drawn to it in Flögel's paper (ref. 5), in which the reversal of the stripes during contraction was first pointed out. I trust, therefore, that it may be permissible to honour Flögel by attaching his name to the body in question. Perhaps, however, some histologists may prefer to term it the *accessory element*, seeing that it gives rise to the

"*accessory stripe*" when the fibrils are in lateral apposition. The broad end of Flögel's element is usually next Dobie's element, but it is occasionally reversed (Pl. XII. figs. 3 and 4). In preparations made from the extensor muscle of the leg I found in one case that Flögel's elements were shaped like minute Bowman's elements; the exceptional form in question is shown in Pl. XII. fig. 2. Flögel's elements may be in contact with Dobie's elements, or there may be a narrow interval between them (figs. 2, 3, 4). Flögel's elements can always be demonstrated in the flexor of the crab's claw, and usually, but not always, in the muscles of the leg; but they are, even in crab's muscle, sometimes reduced to mere granules, as seen by Flögel in the muscle of *Trombidium*; or they may be entirely absent. They are not present in the tail muscle of the lobster, or in human muscle. When they are absent, the shaft of the intermediate segment is perfectly clear on each side of Dobie's element. But even when Flögel's element is present, the shaft of the intermediate segment is always lighter than that of Bowman's element, owing to the small amount of chromatin present.

3. *Clear Segment Proper*.—It is convenient to apply this term to a very delicate clear segment placed between Bowman's element and the intermediate segment. Its average length in the fully-extended fibril is $1.3\ \mu$. It appears to be a fine tubule containing fluid protoplasm without any chromatin.

Effect of Acetic Acid on Extended Fibrils.—The action of acetic acid on extended fibrils of, say, the flexor muscle of the claw is very instructive. The muscle should be fixed in absolute alcohol—not in formol—and stained with heliocine or eosine. When 2 p.c. glacial acetic acid is allowed to act slowly on the fibrils, Bowman's elements gradually swell, their concave shafts become convex and cask-shaped with a regular contour (Pl. XII. fig. 6, A, b). They become very pale and transparent, and show no transverse line crossing the equator to indicate a membrane there. The stained chromatin becomes during the swelling so diffuse, that the swollen element has only a faint pinkish tint. In remarkable contrast to Bowman's element, the intermediate segment shows no tendency to swell even when stronger acid is used (i). The clear segment is somewhat widened at the end continuous with Bowman's element, but at the end continuous

with the intermediate segment it is unswollen. Since there is no ampullation of the clear segment, it may be inferred that it does not appear to contain substances that swell in acetic acid, and that the widening of the end adjacent to Bowman's element is due to the distension of that element. This remarkable difference between the effect of the acid on Bowman's element and on the intermediate segment proves that there is a chemical difference between them; and since the chromatin in the intermediate segment does not swell, it may be inferred that in Bowman's element the swelling is not due to an action of the acid on its chromatin; an inference that can be readily sustained by observing the effect of the acid on contracted Bowman's elements where the chromatin has shifted from the shaft to the ends; the clear shafts swell as before (fig. 6, c). The swelling of the element resembles the swelling of a thread of fibrin under the action of some acids, and probably results from the formation of acid-albumin. I have failed to see any envelope bounding Bowman's element, yet I deem it impossible to doubt the existence of an excessively thin but comparatively tough envelope, bounding not only Bowman's element, but also the clear and intermediate segments. Under the distending force produced by the acid, I have seen Bowman's elements burst and immediately collapse, just as a coloured blood corpuscle does when distended by the influence of 1 p.c. hydrochloric acid. Probably the envelope of the fibril is merely a modification of the outer part of its protoplasm.

It is also instructive to observe the behaviour of small groups of fibrils under the influence of dilute acetic acid. The distension of adjacent Bowman's elements tends to force the fibrils apart, but their separation is mostly prevented by the tenacity with which the intermediate segments cling to each other. I believe the firm adhesion is at the intermediate nodal line.

When entire fibres, fixed with alcohol, are acted on by 2 p.c. acetic or by 1 p.c. formic acid and then torn with needles, the fibre cleaves transversely through the clear segments proper into discs composed of the swollen Bowman's elements and the unswollen intermediate segments (Plate XII. fig. 7). One can observe that Bowman's elements separate very readily when the cover-glass is slightly pressed, but the intermediate segments cling firmly together. This important reaction, first shown by

Rollett (ref. 23), reveals the fact that the fibrillar segments which most readily soften and give way are the clear segments proper.

Arrangement of Fibrils in the Fibre.—The perfect lateral coaptation of corresponding fibrillar segments in the fibre appears due to the intimate adhesion between the intermediate segments. The concavities around the middle of the shafts of Bowman's elements with the sarcoplasma filling them give rise to the appearance of a row of minute ellipses crossing the middle of the broad dim stripe commonly termed Hensen's line. By some histologists the line in question has been ascribed to a membrane crossing the middle of the dim stripe, but there is no such membrane; the apparent line being certainly due to the concavity in the shafts of Bowman's elements and the sarcoplasma between them: it is seen very clearly in contracted fibres (Pl. XII. fig. 19, *h*).

The nomenclature of the transverse stripes of the fibre consequent on the adoption of the terms I have proposed for the fibrillar segments may be arranged in tabular order as follows:

Broad dim stripe, consisting of Bowman's elements and including Hensen's line.

Clear stripe proper, consisting of the clear segments proper.

Intermediate stripe, including { Flögel's line.
Dobie's line.
Flögel's line.

The following are the synonymous terms used by other authors:

Broad dim stripe: { Disque épais (*Ranvier*).
Querscheibe (*Rollett*).

Clear stripe proper: Band J. (*Rollett*).

Flögel's line: { Körnerschicht (*Flögel*).
Disque accessoire (*Fredericq* and *Ranvier*).
Nebenscheibe (*Engelmann* and *Rollett*).

Dobie's line: { Disque mince (*Ranvier*).
Zwischenscheibe (*Rollett*).
Endscheibe (*Merkel*).
Quermembran (*Krause*).
Krause's Membrane.

Hensen's line: { Disque médian (*Fredericq*).
Strie intermédiaire (*Ranvier*).
Mittelscheibe (*Hensen*, *Engelmann*, *Merkel*).

Considering how many terms have been proposed in connection with the microscopic appearances of striped muscle, it may seem surprising that I should have proposed to add to their number; but I trust it may be found that the nomenclature I have suggested tends to simplify a complicated subject, and facilitates description.

Kölliker has applied the term "*muscle columns*" to the bundles of fibrils in a striped fibre, but the nomenclature proposed by Thin (ref. 33) is preferable: he showed that in frog's muscle the fibrils are grouped in small primary bundles, and these again into larger secondary bundles that compose the fibre. In the transverse section of a fibre each Cohnheim's field is the section of a primary bundle. Thin was the first (1876) to demonstrate that after staining with gold chloride, a transverse network is revealed around each primary bundle. He described the network as "composed of exceedingly fine fibres," and that "its meshes accurately correspond to Cohnheim's fields" (ref. 33, p. 252). Retzius (ref. 21) in 1881 described a similar transverse network revealed by the gold process in *Dytiscus* muscle, and pointed out that it occurs at regular intervals crossing the fibre at the sites of the so-called transverse membranes of Krause; and further, that the transverse networks are united by fine longitudinal strands of a similar substance. These observations of Thin and Retzius have been confirmed by Melland (ref. 14) and by Marshall (ref. 15). According to Rollett, these appearances are due to a fibrillated network in the sarcoplasm between the bundles of the contractile fibrils;—elsewhere—that is, between the fibrils in a bundle and under the sarcolemma—the sarcoplasm is nonfibrillated.

Returning to the intimate adhesion between the fibrils at the intermediate nodal line and the transverse sarcoplasmic network between the primary bundles at that line; remembering the annular attachment of the sarcolemma to the sarcous substance at the same line, and noting the fact generally overlooked—that there are annular thickenings on the inner aspect of the sarcolemma at its attachments (Pl. XII. fig. 12, *p*), it is scarcely surprising that Krause should have fallen into the error of supposing that the sarcous substance is intersected at intervals by transverse membranes continued inwards from the sarcolemma.

Rollett (ref. 23, p. 29) regards the so-called transverse membrane of Krause as a thin layer of sarcoplasma intersecting the fibrils in the position of what I have termed the internodal line, and continued between the primary fibrillar bundles as the transverse network of Thin and Retzius, and he regards the transverse layers of sarcoplasma as the medium through which the nerve impulse travels across the fibre from the nerve terminal beneath the sarcolemma to the several fibrillar bundles; and he suggests that the longitudinal strands of sarcoplasm may be the conductors of the impulse to the successive layers of sarcoplasm along the fibre, from which it is communicated to the adjacent fibrillar segments. Without offering any opinion on this theoretical question, which has been discussed by several authors, I would merely observe that the substance of the intermediate nodal line can scarcely be regarded as identical with that of the network of Thin and Retzius, otherwise one would have expected them to have found transverse discs instead of networks stained by the gold. I am aware that in my drawing (Pl. XII. fig. 23) Dobie's lines are stained by the gold as well as the substance between the bundles, but it was not possible to determine whether the staining of Dobie's stripe was due to reduction of the gold in the substance of the internodal band or in the chromatin particles on each side of it. As we all know, the chromatin of the fibrillar segments can be stained by gold as well as the interfibrillar substance. But I am able to make a positive statement with regard to the differential effect of methyl-blue eosine: it stains the substance of the internodal line deeply, and does not stain the sarcoplasm between the fibrils.

UNEXTENDED MUSCLE.—In unextended fibres the clear segments proper of the fibrils are usually invisible, so that the ends of Bowman's elements appear close to the intermediate segments (Pl. XII. fig. 14). When Flögel's elements are absent, the appearance of the fibrils is somewhat puzzling, because there is a perfectly clear stripe between Bowman's elements and Dobie's line. But the addition of acetic acid to the fibre fixed in alcohol in the manner already stated, reveals that the clear band in this case does not consist of the clear stripe proper, but of the shafts of the intermediate segments. Fig. 7, Pl. XII.

shows the effect of 1 per cent. formic acid on an unextended fibre.

Table I. shows measurements of the lengths of fibrillar segments in the flexor muscles of the claws of the same crab,—one fully extended, the other unextended, fixed with formol.

TABLE I.

| Extended. | | Unextended. |
|---------------------------|-------------|---------------------------|
| Bowman's Element, . . . | 9·6 μ . | 8·6 μ . |
| Clear segment, | 1·0 μ . | No clear segment visible. |
| Intermediate segment, . . | 6·6 μ . | 4·3 μ . |

CONTRACTED MUSCLE.

All the phenomena of contraction occur inside each fibril between the node at the equator of Bowman's element and that at the equator of the intermediate segment; therefore the half of Bowman's element, the half of the intermediate segment, and the intervening clear segment proper, constitute the energising unit of the fibril. The portion of tissue included in this unit is extremely small; even in the relatively large fibrillar segments of crab's muscle it is only about 9 μ in length by 0·8 μ in breadth. It is, therefore, scarcely surprising that the visible changes occurring in a mass so small should have proved so puzzling to all observers, but more especially to those who have striven in vain to unravel them by studying the appearances presented by the mass of fibrils in an entire fibre instead of in very small groups of fibrils.

The *first phase* of contraction consists in shortening of the clear and intermediate segments. The *second phase* consists in shortening of Bowman's elements and reversal of the stripes. Assuming the uncontracted fibrils to be fully extended, *the first visible change in contraction consists in shortening of the interval between the ends of Bowman's elements*. The clear segments entirely disappear, and the ends of Bowman's elements come close up to the intermediate segments (Plate XII. figs. 1, B, and

14); shortening of the intermediate segments then begins, Flögel's elements become indistinguishable, and the ends of Bowman's elements approach close to the globules of Dobie's line (fig. 1, C, D; figs. 15, 17). This remarkable shortening occurs without any apparent lateral bulging of the shortened segments; therefore the fluid they contain must either be *pressed or drawn out of them into Bowman's elements*. It is out of the question to suppose that the fluid passes between Bowman's elements, as Krause and others have imagined.

The period at which the *second phase of the contraction*, viz., the shortening of Bowman's elements, begins, appears to vary. I have in many preparations seen the interval between the ends of these elements reduced apparently to little more than the breadth of Dobie's elements before they had begun to shorten and the chromatin to accumulate at their ends. When such is the case, the fibrils have an almost uniformly dim appearance, owing to the invisibility of those portions of the fibril that contain little or no chromatin. This is the so-called "homogeneous stage" of contraction, first noticed by Merkel (ref. 16). In this condition the fibrils are never really homogeneous even in appearance. When suitably stained the globules of Dobie's line can always be seen. Figs. 16 and 22 show the homogeneous stage in fibrils fixed in Müller and spirit, and stained with eosine.

It is, however, also frequently the case that Bowman's elements begin to contract before the shortening of the interval between them and Dobie's line is completed. That is shown in Pl. XII. fig. 1, C, an enlarged copy of the appearances in fig. 5, which was drawn from fibrils, that fortunately showed all the changes from the state of rest (*r*) to that of complete contraction (*t*). That drawing made in 1882 is quite harmonious with the photographs (Pls. XIII. and XIV.) taken at a later time from preparations of the same muscle. The only change made in the drawing has been the addition of Flögel's elements as I afterwards saw them with better methods of fixation and staining. The drawing is also in harmony with the observations of Engelmann (ref. 4), who found, as the result of a large number of measurements, that Bowman's elements begin to shorten before the shortening of the interval between their ends is completed.

During the contraction of Bowman's elements the chromatin

shifts from each half of their shafts to their ends, causing them to swell and become dimmer, and leaving the shafts clear. For a time it is possible to recognise Dobie's line between the adjacent swollen ends of Bowman's elements (Pl. XII. fig. 5, *d'*); but when the contraction is complete, it is usually impossible to distinguish it. The clear stripe of the fully-contracted fibre therefore consists of the shafts of Bowman's elements deprived of chromatin, while the dim stripe is composed of two rows of the dim swollen ends of Bowman's elements, with Dobie's elements and other tissue elements of the intermediate segments between them (Pl. XII. figs. 1, E, F, 18; Pls. XIII. and XIV. figs. 4, 5, 6, 7).

Table II. shows the comparative lengths of fibrillar segments relaxed and contracted in preparations from similar muscles of same crab. The table will be readily understood if it be kept in mind that the *light stripe* of the contracted fibre consists of the shafts of Bowman's elements that have become clear; while the *dim stripe* consists chiefly of the adjacent swollen ends of these elements, with Dobie's line between them.

TABLE II.—*Flexor of Crab's Leg.*

| A Uncontracted and Extended. | B Homogeneous Stage of Contraction. | C More Contracted. | D Still more Contracted. |
|---|--|--------------------------|--------------------------------|
| Bowman's Element, . 8.1 μ | 7.62 μ | Light stripe, 3.37 μ | 2.32 μ |
| Interval between ends of B. Elements, . 8.75 μ | 2.53 μ | Dim stripe, 1.87 μ | 2.25 μ |
| Total lengths, . 16.85 μ | 10.15 μ | 5.24 μ | 4.57 μ |

I have selected the measurements given in Table II. as fairly typical: it is unnecessary to give a larger number, since this part of the subject has been very fully treated by Engelmann (ref. 4).

The effect of 2 p.c. acetic or 1 p.c. formic acid on contracted muscle, previously fixed in alcohol and stained with eosine, is shown in Pl. XII. fig. 6, C; the appearance of the muscle previous to addition of the acid is shown in 6, B. The acid causes

the shafts of Bowman's elements (*b*) to swell (as in the uncontracted fibril, 6, A), but the dim stripe remains unswollen, proving, in the clearest manner, that the light stripe of the contracted fibre is not the light stripe of the relaxed fibre, as was for a long time erroneously supposed.

Taking the above as the main phenomena of contraction visible with the microscope, aided by photographs, the familiar question arises, How are they brought about? More especially, what is the nature of the shortening of the interval between the ends of adjacent Bowman's elements? We have seen that the clear segment first becomes invisible, and that the shortening of the intermediate segment quickly follows. I have already stated why we must believe that fluid passes from these segments into Bowman's element, and I have asserted that it must either be *pressed* or *drawn into Bowman's element*. It is easy to imagine that the clear and intermediate segments are contractile and express their contained fluid into Bowman's elements; when Bowman's elements contract, their chromatin shifts to their ends, probably because it is expressed from the contracting tissue, but the fluid that had passed into them from the clear and intermediate segments is not passed back into them until contraction is ended. It is surely a very remarkable fact, that if fluid is pressed into Bowman's elements before they shorten, that it is not to some extent pressed back again when their contraction occurs. If all the segments of the fibril are contractile, ought we not to have expected them all to undergo similar changes when acted on by acetic acid? Yet we have seen that there is a remarkable difference between the effect on Bowman's elements and on the intermediate segments. More especially, does the chemical difference not point to a probable difference of physiological property? The contraction of striped muscles might be accounted for on another theory—by supposing that Bowman's elements are the only real active agents in contraction, that they cause shortening of the clear and intermediate segments by absorbing fluid from them, and shorten themselves by forcible rearrangement of their micellæ, and in so doing press the chromatin to their ends, but not the absorbed fluid, which they still hold by attraction in their micellar networks. When contraction is over, elastic reaction presses

the fluid chromatin back to its own spaces in the shaft, and the absorbed watery fluid is permitted to return to the intermediate segment, which probably elongates by its own elasticity. On such a theory the intermediate segments would be regarded as passive elastic elements, interposed like elastic buffers between the ends of Bowman's elements. This is obviously the absorption theory of Krause in a new dress, consequent on demonstration of fibrils and their segments, and the visible changes they severally undergo during contraction. But the great difficulty in the way of the absorption theory, even in the above shape, is the rapidity of the process of contraction. All the phenomena, from the beginning to the end of shortening in Crab's muscle, can occur in about half a second; and with the more minute segments of the fibrils in vertebrate muscle, the rapidity is considerably greater. But we must remember, the rapidity with which a heavy fluid like mercury can move within the capillary electrometer is greater than the rapidity of the shortening of muscle; and we must keep in view the possibility of the movement of fluid into Bowman's elements being due to the electrical change which accompanies the contraction. Another point also to be kept in mind is that, judging from the above appearances, a small contraction of a muscle does not involve any shortening of Bowman's elements, but merely of the interval between their ends, and this would have to be accounted for by the process of absorption only. Of course, the very small size of the energising unit as above indicated must not be lost sight of. Nor must one lose sight of the fact that fluid does actually move from segment to segment, whatever theory we adopt as to the cause of its movement. It is needless at present to discuss the theory of contraction at greater length, for evidently it must be left an open question.

The account above given of the visible changes in contracting muscle is entirely in harmony with the descriptions given by Merkel in 1872 and 1881 (refs. 16, 18), and by Fredericq in 1874 (ref. 6), but their methods of preparing the tissue did not enable them to see many of the details above described. The papers published by Rollett in 1891 (refs. 25, 26) certainly show that he has found the phenomena of contraction an extremely puzzling subject. I trust he will investigate the phenomena in

Crab's muscle by the methods above detailed, and that he may be able to confirm my conclusions.

MUSCLE OF LOBSTER.

The muscle of the lobster's limbs is quite similar to that of the crab (Pl. XII. fig. 8), but the latter is greatly to be preferred for the preparation of striped muscle on any extensive scale for teaching purposes, because the muscles of the lobster's pincer are too large to permit of easy penetration of the fixing fluid, and those of the legs are much inferior to those of the crab. The muscles of the tail and back are specially interesting because of the small size of Bowman's elements, and the absence of Flögel's elements (fig. 9). The length of Bowman's elements in the muscles of the pincer claw is 5.8μ , while in the muscles of the back and tail their length is only 3.1μ . The smaller size of the *energising units* in the dorsal and caudal muscles compared with those of the limbs probably have reference to the more rapid contraction of the former. The muscle in question is also interesting because its structure exactly resembles that of vertebrate muscle.

SKELETAL MUSCLE OF VERTEBRATES.

I have examined the tail muscle of the newt (fig. 10), the leg muscle, and infrahyoid muscle of the salamander, the infrahyoid of the frog, the muscle of the dog's diaphragm, and that from an amputated human leg (fig. 11). All were uncontracted, all unextended except the diaphragm, and all were prepared by the same methods as for crab's muscle. In all these varieties of vertebrate muscle the segments of the fibrils exactly resembled those of the tail muscle of the lobster in every respect except their smaller size. In figs. 10 and 11, the muscle was magnified to exactly the same extent as in figs. 8 and 9; they therefore show exactly the comparative size. Bowman's and Dobie's elements were always visible, but no Flögel's elements. In the unextended muscle the whole length of the light interval between the adjacent ends of Bowman's elements may be re-

garded as the intermediate segment. Table III. shows the lengths of Bowman's elements in the vertebrate muscles enumerated above.

TABLE III.

| Lengths of Bowman's Elements and Intermediate Segments, expressed in μ . | | | | | | |
|--|-------|-------------|-------|------|------|---|
| | Newt. | Salamander. | Frog. | Man. | Dog. | The dog's muscle (diaphragm) was forcibly extended before fixation. |
| B. elements | 1.4 | 1.6 | 1.6 | 1.8 | 1.9 | |
| Int' med. segts. | 0.6 | 0.5 | 0.5 | 0.8 | 1.6 | |

The changes in the fibrils of vertebrate muscle during contraction are, as one would expect, similar to those already described in the muscle of arthropods:—the ends of Bowman's elements approach Dobie's line and reversal of the stripes takes place. I observed these changes in the muscle of the frog, but the small size of the fibrillar segments prevented my pursuing this subject further in vertebrate muscle.

THE EFFECT OF CURVATURE ON THE MICROSCOPICAL APPEARANCES OF MUSCLE.

The appearances of striped muscle that have proved so puzzling to the microscopist depend (1) on the fact that the segments of the fibrils are not of uniform calibre; (2) their highly refractile chromatin is not equally distributed in the relaxed, and still less so in the contracted fibrils; (3) when the light is transmitted through the mass of fibrils that constitute a fibre, the effects of curvature and of unequally distributed chromatin are still more complicated by the superposition of many bundles of fibrils: it is easy to understand why observers have arrived at conclusions that have differed so widely from each other. Confusion is inevitable unless it be recognised by all that the fibrils must be studied singly and in very small groups, and that they must be suitably fixed and stained to permit of their characters being rightly apprehended. The effect of curvature is well seen in the examination of Bowman's elements in a group of three or four

fibrils. The rays rendered divergent by the concavity in the middle third of their shafts cannot be focussed with the same position of the lens as the parallel or convergent rays transmitted by their ends; therefore, with a superficial focus the ends are light and the centre dim, while these appearances are reversed with a deeper focus. Fig. 22 shows portions of three fibrils of crab's muscle in the "homogeneous" stage of contraction. A was drawn with a "superficial" and B with a "deeper focus," to show the reversal of the light and dim appearances due to curvatures in the fibrils, and difference of refractive index between the fibrils and the intervening sarcoplasma. The optical effects of curvature are also well seen in the photograph of contracted muscle shown in Pl. XIV. fig. 5 (see description of fig.). The old theory that the peculiar appearances of striped muscle are all due to curvature was skilfully criticised and then dismissed by Dobie in 1848; and it is, indeed, remarkable that the old exploded theory should have been revived by Haycraft (ref. 9), and persistently advocated by him so late as 1891 (ref. 10). Previous to the publication of his later paper, he had for several years every opportunity of examining all my preparations of muscle, including those drawn in Pl. XII. figs. 13-18, which he heard me describe in 1881 and on several subsequent occasions; yet in his later paper (ref. 10, p. 297) he states that "the fibrils are varicose, and have a different refractive index from the interfibrillar matter in which they lie: they in consequence present the optical striping possessed by all such bodies under similar circumstances; and *we have no reason to suppose that this striping has any other interpretation.*" (The italics are mine.) To prop up his untenable theory, he ignored Bowman's elements, the comparative effects of acids on them and the intermediate segments, the effects of dyes on the chromatin; and directed special attention to the production of collodion casts of striped muscle, showing that moulds can be taken of superficial curvatures that exhibit stripes corresponding to Dobie's and Bowman's stripes. I can scarcely believe that any histologist who has studied muscle with an unbiassed mind can be misled by such superficial treatment of an intricate subject.

APPEARANCES OF STRIPED MUSCLE IN POLARISED LIGHT.

The statements made by able observers regarding the appearances of striped muscle in polarised light are in some particulars remarkably contradictory. The chief cause of the discrepancy has been the failure of some observers to perceive that observations made on entire fibres are, from the nature of the tissue, very liable to fallacy, and that very small groups of fibrils should be chosen for examination.

My observations have been made entirely on fibrils fixed with alcohol, formol, or Müller and spirit, and mounted in glycerine. I used the well-known polariscope of Hartnack and Prazmowski with oxyhydrogen light, in the path of which a sheet of green glass may be interposed between the lamp and the microscope with advantage. All are agreed that in the uncontracted fibre Brücke rightly described the sarcous elements as anisotropic.

According to Engelmann (ref. 3) all the rest of the sarcous substance is isotropic, but I believe he stands alone in this opinion. When small groups of fibrils are examined, it can be clearly seen that Dobie's elements are anisotropic, as Brücke, Flögel, Merkel, and Fredericq have stated, although they alluded to these elements under different names (p. 323). The shaft of the intermediate segment on each side of Dobie's line I find to be isotropic *if it contain no chromatin*, but when Flögel's elements are present they are anisotropic as Fredericq (ref. 6, p. 41) correctly stated: he described them as the "secondary" or accessory disc. The clear segments proper and the interfibrillar substance are isotropic.

Conflicting statements have also been made regarding the contracted fibre: Merkel and Fredericq found that in the "homogeneous" or "intermediate" stage of contraction, when the ends of Bowman's elements have approached closely to Dobie's line, there is no longer any isotropic substance to be seen between the ends of Bowman's elements and Dobie's line. But I entirely dispute the statement that there is a thin layer of isotropic substance crossing the equator of Bowman's elements. The error has arisen from the fact that the middle

portion of each element is surrounded by a shallow furrow filled with isotropic sarcoplasma, so that, if a fibre or large group of fibrils be examined with crossed nicols, a dim stripe is seen crossing the middle of the bright band, due to the double refraction of Bowman's elements. With regard to the stage of complete contraction in which the shafts of Bowman's elements have been left clear owing to shifting of the chromatin to their ends, Flögel rightly stated that the shafts remain anisotropic. His statement regarding the *dim band of the contracted fibre* was at first indefinite, but in an appendix to his paper (ref. 5, p. 78) he states definitely that the whole of the dim band is doubly refractile. He was not aware that the "granules" on each side of Dobie's line in the contracted fibre are the ends of the "sarcous elements" swollen with chromatin. He erroneously regarded them as his "granule layer." Merkel (ref. 18, p. 688) arrived at the same conclusion as Flögel regarding the double refraction of both dim and light stripes in the contracted fibre; but Fredericq, while agreeing that the dim band is anisotropic, stated that the light stripe consisting of the clear shafts of Bowman's elements is isotropic (ref. 6, p. 49). On the other hand, Engelmann (ref. 3) has arrived at the very opposite conclusion: to him the *dim stripe* of the contracted fibre is *isotropic*, while the *clear stripe* is *anisotropic*.

Engelmann's illustrations of striped muscle as seen with polarised light have been copied into the text-books, and his statements have been taken by some authors as satisfactory, yet it is not difficult to prove that they are erroneous. The dim bands of the contracted fibre principally consist of accumulated chromatin; when viewed with crossed nicols they are quite bright, and therefore doubly refractile; but the shafts of Bowman's elements are by no means so bright as they are in the uncontracted fibrils, and not nearly so bright as the stripes that contain the shifted chromatin. I therefore agree with the statements of Flögel and Merkel. I am convinced that the chromatin of the fibrils is a doubly refractile fluid substance; that the *tissue* of Bowman's elements is also doubly refractile, although feebly so; that the shaft of the intermediate segment is highly refractile unless it contain chromatin, and that the clear segment appears to be always singly refractile.

In view, however, of the discrepancy of the statement regarding the isotropic and anisotropic parts of the sarcous matter, it seems to me very desirable that in describing the structure of the sarcous substance, reference to its appearances in polarised light should be avoided until all the appearances in ordinary light have been detailed, otherwise confusion and misapprehension are inevitable.

OBSERVATIONS ON THE THEORIES OF SOME OTHER AUTHORS.

Having declared myself a supporter of the fibrillar theory of striped muscle, it follows that I am in harmony with Kölliker, Merkel, Fredericq, and Rollett; and that I entirely disagree with the opinions of Krause, Engelmann, Klein, Marshall, Melland, van Gehuchten, and others who have advocated the doctrine originally started by Bowman, that the fibrils result from post-mortem cleavage of the sarcous substance. After the adverse criticisms on the erroneous theory of Carnoy and Marshall, who raised the sarcoplasma to the dignity of a contractile network, and degraded the substance of the fibrils into a passive *enchylema*, it seems needless to dwell on a doctrine so untenable; but the new theory advanced by Schäfer (ref. 32) ought not to be left unnoticed, because of the eminence of the author and the great influence he exercises on the teaching and study of histology, as the editor of the histological portions of *Quain's Anatomy* that has long been a leading text-book in this country. He regards "the wing muscles of insects as furnishing the key to the proper understanding of the structure of muscle" (*Quain's Anat.*, 10th ed.). Each fibre is "a large bundle of *muscle columns*" or *sarcostyles* embedded in a considerable amount of sarcoplasm enclosed within sarcolemma. The term "*sarcostyle*" is only another name for *primary bundle* of fibrils. Adopting Krause's old "casket theory," he regards the sarcostyle as divided at regular intervals by Krause's transverse membranes into "*muscle segments*" or "*sarcomeres*," which are only new names for Krause's "muscle caskets." Krause (ref. 12) stated that the sarcous matter in each compartment consists of a row of sarcous elements with a fluid-like substance between

them, and filling the portion of the light stripe between their ends and his transverse membrane. Schäfer gives to the time-honoured term sarcous element a new significance: he now applies this name to the portion of sarcous matter in the "sarcomere" that stains with hæmatoxylin. This "sarcous element" is a strongly refracting disc-like structure, separated from Krause's membrane by "a clear interval occupied by hyaline substance." It is "pierced by short tubular canals that extend from the clear interval as far as the middle of the disc," where there is "a median clear interval that corresponds with the line of Hensen." "These canals give it a longitudinally striated appearance." During contraction, fluid is absorbed into the visible pores of the discoid "sarcous element," so that "its ends approach the membranes of Krause." This new theory of muscle is obviously only a new version of Krause's theory. Although Krause supposed that during contraction fluid passes from it *between* the sarcous elements of Bowman, he did at all events recognise these elements as discrete rod-like bodies. I trust Schäfer may be induced to recognise that this new theory is as erroneous as his old theory of "muscle-rods," and that students of histology will be spared much perplexity if he withdraw it. I have examined the wing muscles of the blow-fly fixed with alcohol, stained with heliocine and mounted in glycerine, and I find that the segments of the fibrils are precisely similar to those of vertebrate muscle. Bowman's elements have their typical shape, the globules of Dobie's line are visible, but there are no Flögel's elements. The homogeneous stage of contraction with the ends of B. elements close to Dobie's line, and also the further stage of contraction showing complete reversal, were seen.

I cannot close this paper without referring more particularly to Rollett's elaborate researches on striped muscle published in 1885 and 1891. His research has had reference principally to the structure of muscle in beetles, of which he has examined some three hundred varieties. His papers contain many interesting observations regarding the relative arrangements of fibrils and sarcoplasma, the terminations of nerves, the effect of acids on the sarcous substance, and its cleavage into discs. He has to a large extent studied the fibres in their living state,

or fixed with alcohol or osmic acid. His chief staining agents were gold chloride and hæmatoxylin. I confess that when I received his elaborate papers I expected that he must have left little for me to add, but on perusing them I perceived that he had left abundance of room for this communication.

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DESCRIPTION OF PLATES.

PLATE XII.

Significance of Letters frequently repeated in the Drawings.

| | |
|--------------------------|-----------------------------|
| b. Bowman's elements. | h. Hensen's line. |
| c. Clear segment proper. | i. Intermediate segment. |
| d. Dobie's elements. | n. Intermediate nodal line. |
| f. Flögel's elements. | |

Fig. 1.—Semischematic representation of portions of fibrils of crab's muscle, showing the appearances of the fibrillar segments in the several stages from complete relaxation to complete contraction. Muscle fixed with Müller and spirit, and stained with eosine. The segments of the fibrils are drawn to scale as regards length, but their breadth is doubled, and the increase in breadth during contraction in C, D, E, F is only approximative.

A. Portion of a fibril uncontracted and extended to its full normal length. *b*, Bowman's element; *i*, intermediate segment; *d*, Dobie's element, consisting of two hemispheres of chromatin (*a*, *a*), and a transverse nodal line between them (*n*); *f*, Flögel's element; *c*, clear segment proper.

B. First stage of contraction. Shortening first appears in the interval between ends of Bowman's elements. The clear segments have disappeared, and the clear interval between Flögel's elements and Dobie's elements has also disappeared, indicating slight shortening of the intermediate segment. There is as yet no shortening of Bowman's elements.

C. A later stage of contraction. Bowman's elements have now begun to shorten, and the shortening of the intermediate segment has increased.

D. A still later stage of contraction. Intermediate segment so much shortened that Flögel's elements are no longer visible, and the ends of Bowman's elements have come very near to Dobie's element. Bowman's elements are slightly shortened, and the chromatin has partially shifted from their shafts to their ends, causing the latter to swell.

E. A still later stage of contraction. Bowman's elements are still more shortened, their ends are swollen with chromatin, and Dobie's element is no longer clearly visible between them.

F. Complete contraction, showing Bowman's elements still shorter, their shafts now clear, owing to complete shifting of the chromatin to their ends.

Figs. 2, 3, 4.—Small bundles of fibrils from extensor of leg of different crabs uncontracted and extended to full normal length: formol; heliocine; glycerine (*Zeiss* $\frac{1}{2}$ *homogen. obj.*). Figs. 3 and 4 are drawn on a lower scale than fig. 2. Bowman's elements (*b*), Dobie's elements (*d*), and the clear segments proper (*c*) are similar in each bundle, but Flögel's elements differ in each case. Fig. 3 shows their usual appearance, in which the broader end of the pear-shaped particle is next Dobie's element. In fig. 4, the narrower end is next Dobie's element. In fig. 2, their appearance is quite exceptional, resembling that of minute Bowman's elements. In figs. 2 and 4 there is a narrow, clear interval between Flögel's and Dobie's elements which is absent in fig. 3. In fig. 2, A, a single fibril is shown. In figs. 2, 3, 4, *h* indicates Hensen's line resulting from annular furrows surrounding the middle third of Bowman's elements, filled with sarcoplasma, and appearing as elliptical spaces in the optical section.

Fig. 5.—Three fibrils of crab's leg muscle, showing the successive stages from complete relaxation (*r*) to complete contraction (*t*). *b* to *b*¹⁰ show the various appearances of Bowman's elements; *d* to *d*⁹, the appearances of Dobie's elements; *f* to *f*², the appearances of Flögel's elements. *c*, Clear segments proper. Müller and sp.; eosine; glycerine. The semischematic representation of fibrils shown in fig. 1 is taken from this drawing. Flögel's elements were seen only as apparent granules when this drawing was made (see fig. 20), but

to render the drawing more complete they have been introduced as afterwards seen by staining with heliocine. (Camera lucida, Zeiss $\frac{1}{18}$ homogen. obj.)

Fig. 6, A.—Uncontracted and fully extended fibril of muscle of crab's leg, fixed with absolute alcohol, stained with heliocine, and then treated with acetic acid and glycerine. *b*, Bowman's element swollen. *i*, Intermediate segments not swollen. *c*, Clear segment, swollen only at end connected with Bowman's element. (Zeiss $\frac{1}{12}$ homogen. obj.) B. Contracted muscle prepared as above, showing appearance of a bundle of fibrils before addition of acetic acid. *b*, Bowman's elements; *h*, Hensen's line. C. The same bundle of fibrils after addition of acetic acid.

Fig. 7.—Portion of uncontracted and unextended fibre of leg muscle of crab after fixation with absolute alcohol, staining with eosine, and addition of 1 p.c. formic acid. *b*, Bowman's elements swollen and rendered very clear; *i*, intermediate segments not swollen; *d*, Dobie's line. Pressure with a needle on cover-glass caused disc consisting of intermediate segments to tear away, and several Bowman's elements to fall out of position at *b*. (Camera lucida, Zeiss F. obj.)

Fig. 8.—Fibrils of muscle of distal segment of pincer claw of lobster uncontracted and extended to full normal length: corrosive sublimate and alcohol; eosine; glycerine. (Zeiss $\frac{1}{18}$ homogen. obj.)

Fig. 9.—Fibrils of muscle of lobster's tail uncontracted and extended to full normal length. Prepared in same manner as muscle of pincer. The segments of the fibrils are much smaller, and Flögel's elements are absent. (Drawn to same scale as Fig. 8.)

Fig. 10.—Small bundle of fibrils of muscle of newt from root of tail uncontracted and extended to normal length. Fixed with corrosive sublimate and alcohol. Stained with heliocine and examined in balsam. *b*, Bowman's elements. *d*, Dobie's line. No Flögel's elements. (Zeiss $\frac{1}{18}$ homogen. obj.)

Fig. 11.—Bundle of fibrils from muscle of human leg uncontracted. Müller and spirit; eosine; glycerine. (Zeiss $\frac{1}{18}$ homogen. obj.)

Fig. 12.—Portion of a fibre of crab's leg muscle, showing sarcolemma (*o*) with annular thickenings attached to Dobie's lines (*d*). The thickenings are seen in the sarcolemma detached at right side of drawing (*p*). *b*, Bowman's elements. Müller and sp.; eosine; glycerine. (Zeiss 4 mm. apochromatic obj.)

Figs. 13, 14, 15, 16, 17, 18 are the series of drawings of muscle of crab's leg made for me by R. J. Harvey Gibson in 1881. All the drawings made to same scale, with the aid of camera lucida. No change has been made in the drawings. Flögel's elements were seen only as granules. Hensen's line (*h*) was at that time erroneously thought to be due to a swelling in the middle of Bowman's element. Müller and spirit; eosine; glycerine. (Zeiss F. obj.)

The series shows all the successive stages from complete relaxation (fig. 13) to complete contraction (fig. 18). It will be observed that in 16 no shortening of Bowman's elements appeared to have taken place, although the interval between their ends was completely

shortened. The appearance therefore differs from that shown in fig. 1, C, and in fig. 5, b^2 .

Fig. 16 gives a typical illustration of Merkel's "homogeneous" stage of contraction (see fig. 22).

Fig. 19.—A bundle of contracted fibrils of crab's leg muscle, treated with ammonium molybdate. The yellowish brown colour given to the chromatin is not reproduced here. (*Zeiss $\frac{1}{2}$ homogen. obj.*)

Fig. 20.—Fibrils of muscle of crab's leg uncontracted and extended to full normal length. Flögel's elements were seen only as granules of chromatin (*f*). A is intended to show effect of shrinkage on clear (*c*) and intermediate segments (*i*). B. Fibril unshrunk. C. Bundle of fibrils. The scale of drawing is nearly the double of that of figs. 13 to 18 (Müller and sp.; eosine; glycerine).

Fig. 21.—Bundle of fibrils of crab's muscle uncontracted and unextended. Bowman's elements appear to be in contact with ends of intermediate segments. Flögel's granules and the clear segments proper between them and Bowman's elements are not seen.

Fig. 22.—The so-called homogeneous stage of contraction. The ends of Bowman's elements (*e, e*) appear close to Dobie's line. A was drawn with a superficial, and B with a deep focus from same muscle as fig. 16. (*Zeiss $\frac{1}{8}$ homogen. obj.*)

Fig. 23.—Flexor muscle of pincer of crab stained with gold chloride by Melland's method. A. Primary bundles of fibrils (*l*), outlined by longitudinal gold lines, with rounded deeply-stained particles opposite Dobie's lines (*d*). B. Optical transverse sections of the same bundles. C shows the relative size of a single fibril; *b*, Bowman's element. (*Zeiss E. obj.*)

The above illustrations were drawn at different times on different scales of amplification. In figs. 3, 4, 5, 20, 21 the scale is double and in fig. 22 it is three times that of figs. 13 to 19. The relative size of the elements in different muscles is given in the text.

PLATES XIII. AND XIV.

All the photographs are taken from the leg muscle of the crab. The muscle in fig. 1 was fixed with formol, stained with heliocine, and examined in glycerine. The muscle in all the other figs. was fixed with Müller and spirit, stained with eosine, and examined in glycerine. Figs. 2–6 were taken in 1890 by the late Mr A. Schulze, from the preparations shown by the author at the Internat. Med. Congress in 1881. Figs. 1 and 7 were recently taken by my assistant, Dr E. W. Carrier.

Unfortunately, the original negatives of figs. 2, 3, 4, and 6 were lost, so that new negatives had to be taken from lantern slides, with an unsatisfactory result in the case of fig. 2.

ON THE MYOLOGY OF *DOLICHOTIS PATAGONICA*
AND *DASYPROCTA ISTHMICA*. By BERTRAM C. A.
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MR BEDDARD¹ has published some notes on the anatomy of the Patagonian Cavy; and that of *Dasyprocta cristata*, the West Indian Agouti, has been studied by Messrs Mivart and Murie,² and, in common with that of other rodents, by Mr Parsons.³ The following notes contain an account of the muscular system of a second specimen of *Dolichotis*, and of that of the Central American agouti, *D. isthmica*. I have omitted mention in these notes, for the sake of brevity, of many muscles, the conditions of which do not markedly differ from that described by the above observers. As I have called attention to the fact of the absence of certain muscles, it will be understood that the omission of the name of a muscle does not mean that it was not present, but that there was no special reason for drawing attention to it.

MUSCLES OF THE HEAD, NECK, AND BODY.

The *Masseter* in both these animals, as indeed in all rodents, was remarkably well developed, presenting in each all four of the typical divisions mentioned by Parsons, though in neither case was there a complete separation between the posterior deep and posterior superficial portions. In *Dolichotis* the tendon of the anterior superficial part was provided with a large fibro-cartilaginous fabella, about the size of a haricot bean, which played over a distinct bony prominence on the outer aspect of the mandible, a bursa intervening. This tendon, as far as the fabella, was distinctly double, one part belonging to the fibres

¹ "Notes on the Anatomy of *Dolichotis patagonica*," *Proc. Zool. Soc.*, 1891, p. 236.

² "On the Anatomy of the Crested Agouti," *Proc. Zool. Soc.*, 1866, p. 383.

³ "On the Myology of the Sciuromorphine and Hystricomorphine Rodents," *Proc. Zool. Soc.*, 1894, p. 251.

from the margin of the ramus, the other to those coming from its deeper (internal) surface. A similar duplicity of the tendon was observed in the agouti, but there was no fabella. In *Dolichotis*, again, the tendon of the anterior deep part also possessed a fabella, of smaller size, which played against the inner aspect of the anterior prolongation of the zygoma. This fabella was absent in *Dasyprocta*. In all other respects the attachments were as described by Parsons, and the same may be said with respect to the *temporal* and *facial* muscles. *Dolichotis*, as might be expected in an animal with such large ears, had a full set of well-developed ear-muscles, viz.—(1) *Retrahens*, which arose from the ligamentum nuchæ over the first and part of the second cervical spines. It was a large muscle, whose fibres passed to the inner and posterior aspect of the base of the auricle. (2) *Attrahens* arose above the orbit and passed to the anterior aspect of the base of the auricle, just in front of (3) *Adductor anterior*, which, with its fellow of the opposite side, formed a digastric muscle connected with a central fibrous raphé, which did not appear to have any bony attachment. (4) *Adductor posterior* lay under cover of the *retrahens*, than which it was much smaller. Arising from the posterior part of the skull, it passed directly outwards, to be inserted beneath *retrahens*. (5) *Rotator* arose from the back of the occiput, passed forward side by side with its companion, from which more anteriorly it diverged, to be inserted with the anterior adductor. The action of this muscle is to turn the pinna round, so that its concavity is directed forward. (6) *Abductor* or *depressor*: this muscle arose from the bone below and in front of the antero-external part of the base of the pinna, into which it was inserted.

The *Digastric* in *Dolichotis* was narrowed centrally, and possessed a tendinous superficies, but not a central tendon; its connection with the hyoid was very slight. In *Dasyprocta* the muscle presented an interesting condition. There was no central tendon, though one is described in *D. cristata* by Mivart and Murie, but a superficial tendinous plane near the centre, as in *Dolichotis*. Over and above this, however, there arose from the posterior (lower) border a slender round tendon, which passed across the neck, and joined with its fellow of the opposite side to form a tendinous arcade from which the mylo-hyoid arose.

This recalls the condition described by Parsons in the Sciuromorpha, *e.g.*, Pteromys, where the posterior bellies end entirely in tendons, which unite to form an arcade from which arise the anterior bellies and parts of the mylo-hyoid. But the conditions are not identical, since careful dissection in *D. isthmica* showed that by far the greater number (at least five-sixths) of the fibres of the posterior bellies passed into the anterior direct, only a small part being connected with the intermediate tendon. It is probable that the condition thus described in *D. isthmica* is intermediate between that met with in forms such as Dolichotis and that observed in the Sciuromorpha.

Neither animal possessed a *transverse mandibular*, and both had the normal three *styloidean* muscles. *Sterno-mastoid* was in Dolichotis a very slender muscle, attached above internally to *Cleido-mastoid*. The latter, which was much the smaller of the two in Dasypsecta, arose from the bony clavicle for a short distance outwards from its fibrous sternal extremity. *Omo-hyoid* was absent in both. *Levator claviculæ* arose in both from the basi-occipital; in Mivart and Murie's agouti it arose in the same way; in Parson's, from the ventral arch of the atlas.

In both animals *Scalenus anticus* extended, in a ventral position to the subclavian artery, from the first rib to the basi-occipital, where it was attached posterior to the levator claviculæ. *Scalenus medius et posticus* in Dolichotis extended from the third to the seventh cervical processes inclusively, to the upper three ribs. In Dasypsecta this stratum arose from the transverse processes of all the cervical vertebræ and passed to the upper three ribs. In this animal very distinct tendons arose from the fifth, sixth, and seventh processes, which, perforating the deeper or posticus fibres, joined the more superficial or medius layer. In both forms there were distinct *splenii capitis* and *colli*. The *Serratus posticus* extended in Dolichotis from the fifth, and in Dasypsecta from the third to the last rib, and in each it formed only one stratum.

MUSCLES OF THE ANTERIOR EXTREMITY.

Trapezius, *Deltoid*, the *Pectorals*, and *Sterno-scapularis* were as described by Parsons, and the only further noteworthy features

about these muscles were, (a) the low insertion of the clavicular deltoid on the humerus,—an insertion quite distinct from that of the middle and posterior parts, which were attached to the deltoid ridge on the humerus. The fibres of the clavicular part were, on the contrary, inserted into the front of the bone a short distance above its lower end. (b) On one side in *Dolichotis* a slip arose from the deeper of the two more anterior pectoral strata which joined the sterno-scapularis, or rather, the costo-clavicular part of that muscle. This slip did not exist upon the other side. The occipital *Rhomboid* was smaller in *Dolichotis*, and distinct from the rest of the muscle; in *Dasyprocta* its origin was much wider, and it formed a part of a continuous sheet with the remainder of the rhomboid stratum. *Levator anguli scapulae* and *Serratus magnus* formed a continuous sheet in both animals, which in *Dolichotis* extended from the third to the seventh cervical vertebra, and from the first to the ninth rib; and in *Dasyprocta*, from all the cervical vertebrae, and from the first to the eighth rib.

Latissimus dorsi arose from as high as the sixth dorsal spine in *Dolichotis*, and the fourth in *Dasyprocta*, and was inserted into the usual position on the humerus. In both there was a very weak *dorsi-epitrochlearis*. In *Dolichotis* this muscle was apparently much weaker than in the specimen dissected by Beddard, to judge from his figure of the muscles of the arm; indeed, on one side it was reduced to the condition of a band of fascia, containing a few muscular fibres above, and fusing below with the aponeurosis of the triceps. In *Dasyprocta* it was somewhat stronger, but even in that animal it did not reach the olecranon, but terminated by fusing with the inner head of the triceps. *Teres major* was in both forms inserted near to, but separate from and in front of, the *latissimus dorsi*. In *Dolichotis*, Beddard describes this muscle as inserted, "in common with the *latissimus dorsi*, by a flat tendon about half an inch long, and rather more than half an inch broad at its insertion." In my specimen the attachments of the two muscles were quite distinct. As regards *Dasyprocta*, my specimen agrees with that dissected by Parsons, and differs from that of Mivart and Murie. *Teres minor* was associated at its origin with *infra-spinatus*, but not at its insertion, the former being attached to the neck of the

humerus, and the latter by a broad, flat tendon, beneath which was a bursa, to the inner part of the head of the same. Both animals possessed a single-headed *biceps*, inserted in Dolichotis partly into the fascia over the forearm, and partly by an oblique sling tendon which extended from the tubercle of the radius above to the ulna at a lower level. This tendon passed under the pronator radii teres, and lay superficial to that of the *brachialis anticus*. The last-named muscle possessed in Dolichotis only one head, the outer; nor was the muscle marked as x in Beddard's diagram, which apparently represented the inner head, present on either side. The inner head was present, however, in Dasypsecta. In both animals this muscle was inserted into the ulna; and in Dolichotis, as has been above stated, its tendon passed beneath the sling tendon of the biceps, to reach its place of insertion on the ulna. *Coraco-brachialis* was represented by its two upper portions in both animals, though in Beddard's specimen only the middle existed.

Triceps.—In Dolichotis this muscle consisted of the following portions:—(a) *Externus* arose from the tendon of the infra-spinatus and from the humerus, below the insertion of this muscle, for its upper third, and was inserted, almost independently of the other parts, into the outer side of the olecranon. (b) *Longus* arose from one-third of the axillary border of the scapula and from the edge of the infra-spinatus. It developed a tendon on its deep surface, which became attached to the posterior and upper aspect of the olecranon. To the inner side of this tendon the part of the muscle in question gave off a fleshy tongue, which ended in a shorter tendon, which became continuous with that of the next portion. (c) *Internus* arose from the neck of the humerus only, and was inserted into the inner aspect of the olecranon. (d) *Profundus* arose from the whole of the posterior surface of the humerus, extending from the neck to the upper margin of the olecranon fossa, and was inserted into the anterior end of the upper aspect of the olecranon and into the posterior part of the capsule of the elbow-joint. In Dasypsecta there were only the three portions recognised in human anatomy.

Pronator radii teres was a small single-headed muscle in Dolichotis, inserted into the junction of the upper and second fourths of the radius; in Dasypsecta, into the centre of that bone.

Flexor sublimis digitorum was in *Dolichotis* an excessively small muscle, as described by Beddard. It arose from the superficial aspect of the broad, common, deep flexor tendon a short distance above the wrist. It ended in three slender tendons for the second, third, and fourth digits. In *Dasyprocta* it was a larger muscle, lying to the ulnar side of the condylar heads of the profundus layer, which ended in tendons for the third and fourth digits, the second and fifth receiving theirs from the flexor brevis manus. The *deep flexor mass* consisted of those elements which I have already described¹ as typically making up that muscle, viz., condylo-radialis, condylo-ulnaris, centralis, radialis, and ulnaris. The two last-mentioned elements were very small. Beddard does not appear to have noticed the *centralis* element, which was very well developed and distinct on both sides in my specimen. I notice that this head of the deep flexor is very often overlooked, as may very easily happen, although it is, so far as my observations go, a very constant factor. If the tendons of the condylar heads be divided near their point of junction with those of the radial and ulnar parts, and turned backwards so that their deep surface is exposed, the centralis will generally be discovered packed away between the other heads. It is much more easy to miss it if the condylar heads are divided near their origin and turned downwards. In *Dasyprocta* I found only two of the condylar heads, and the radialis proprius was very small, a fact correlated, no doubt, with the diminutive state of the pollex. In the previous paper of mine on the flexor muscles, to which I have already alluded, I came to the conclusion that in *D. cristata*, it was the centralis element which was absent, and that certainly is the least constant of them all. I am inclined to think that in *D. isthmica* it is condylo-radialis which is wanting, from the somewhat deep situation of the more radial of the two tendons coming from the condyle. *Pronator quadratus* in *Dolichotis* was converted into a stout quadrilateral sheet of fibrous tissue, which firmly united the radius and ulnar at their lower extremities. *Supinator brevis* was also apparently represented by a fibrous band passing from the external condyle of the humerus to the ulna at a short distance from the elbow-joint, and quite separate from any

¹ "The Flexors of the Digits of the Hand," *Journal of Anatomy and Physiology*, vol. xxiv. p. 72.

of its ligaments. The retrograde condition of these muscles is no doubt correlated with the position of permanent pronation which is occupied by the bones of the forearm. In *Dasyprocta*, pronator quadratus formed a thin but extensive sheet, which occupied the whole length of the inner borders of both bones; and supinator brevis was a small unilaminar muscle, the posterior interosseous nerve lying between it and the bone. I did not find a *palmaris longus* or a *supinator longus* in either animal. The *extensors* in *Dolichotis* were as follows:—(1) *E. carpi radialis longior* and *brevior*, single above, and ending below in two tendons, attached one to the back of the second, the other to the back of the third metacarpal bone. (2) *E. communis digitorum*, which ended in tendons for all four digits. (3) *E. minimi digiti et annularis*. (4) *E. metacarpi pollicis*: this muscle, which was not noticed by Beddard in his specimen, consisted almost entirely of fibrous tissue, only a small amount of muscular fibre existing near its origin. It wound round the bone in the usual manner, over the tendons of the radial carpal extensors, as a broad glistening tendon, which reached the usual insertion. (5) *E. carpi ulnaris*. In *Dasyprocta* the extensors were:—(1) *E. carpi radialis longior* and *brevior*, arranged as in *Dolichotis*. (2) *E. communis digitorum*. (3) *E. minimi digiti et annularis*. (4) *E. metacarpi pollicis*, inserted by one slip into the base of the metacarpal bone of the pollex, and by another into the lower and external part of the palmar ossicle. (5) *E. indicis*, which on both sides sent a fine slip to the pollex. (6) *E. medii*: I found a very tiny representative of this on one side. It is probably quite an unusual occurrence, as it does not seem to have been seen by Parsons, or by Mivart and Murie. (7) *E. carpi ulnaris*.

Short muscles of the hand.—*Dolichotis* had superficial adductors for the pollex and minimus, the latter being the stronger; in *Dasyprocta* these muscles were connected with index and minimus. In both animals pollex and minimus possessed also an abductor, and there were paired flexores breves for the other digits. The *flexor brevis manus* in *Dasyprocta* arose from the superficial aspect of the flexor tendons, and ended in slips for the second and fifth digits. In Mivart and Murie's specimen it was connected with the fifth digit only.

MUSCLES OF THE LOWER EXTREMITY.

Biceps was in both animals a very thick, strong muscle. In *Dolichotis* it arose by muscular fibres and by fascia from the upper caudal vertebræ, this being the chief head; and also by a thin, flat tendon from the anterior border of the ischial tuberosity. The caudal head developed a superficial tendon, which became round and thick, and was inserted into the outer side of the patella. The ischial fibres joined the deeper surface of this tendon. From its lower border there was continued downwards a fascia, which partly ended over the muscles of the leg, partly was continued down over the tendo Achillis, for which, with similar prolongations from the other two hamstring muscles and the gracilis, it formed a kind of encapsulating sheath. Still further on, this composite sheath formed a cap over the posterior extremity of the os calcis, and separated from it by a bursa. This cap was joined on its inner side—in fact, largely formed on that aspect—by the tendon of the plantaris, and from it was derived the fibrous representative of the flexor brevis digitorum. Thus all the hamstring muscles are enabled to act as flexors of the toes and extensors of the ankles, as well as being extensors of the hip and flexors of the knee, their action causing all the movements executed by the different segments of the hinder extremity in running, walking, or leaping. The arrangement in *Dasyprocta* is very similar.

Semi-tendinosus arose in *Dolichotis* from the upper three caudal vertebræ and from the posterior border of the ischial tuberosity, and was inserted by a distinct tendon into the crest of the tibia and by a fascial prolongation over the side of the leg, and with the other tendons as mentioned in the description of the preceding muscle. The arrangement was similar in *Dasyprocta*, but the ischial head was weaker than in *Dolichotis*. *Semi-membranosus* was as described by Parsons. The main part was stronger in *Dolichotis* than in *Dasyprocta*. In both it was very much inclosed by the other portion of the muscle and the adjacent adductor mass, so that it was only possible to isolate it by following up the thick, round tendon by which at its lower part it was attached to the tibia.

Gracilis consisted in *Dolichotis* of two parts: (a) upper, outer,

and larger, connected on its outer side with the sartorius, and inserted with it into the inner side of the patella, and thence as far as the inner tuberosity of the tibia; (b) inner, lower, and smaller, attached to the inner side of the tibia, and prolonged down with the other above-mentioned tendons over the tendo Achillis. In *Dasyprocta* I found a practically continuous sheet representing these two portions. There was some trace of division, and particularly near its origin, but not enough to warrant its being described as a double muscle.

Gluteus maximus was in both animals a very small muscle, and formed part of a continuous sheet, which also represented *Tensor vaginae femoris* and *sartorius*. Below, the *gluteus maximus* terminated in a thin, flat tendon, which was inserted into the posterior part of the shaft of the femur near its lower end. The *sartorius* part of the sheet was much better marked in *Dolichotis*, where it blended below with the tendon of the quadriceps, than in *Dasyprocta*. *Gluteus medius* was very large and strong in both. There was also a well-marked *Scansorius*, with a very strong tendon, attached to a tubercle on the femur at the junction of the great trochanter and the shaft. Some of the fibres of the *gluteus minimus* were attached to this tendon, but for the most part they were inserted separately. *Pyriformis* was quite distinct from the other muscles. *Pectineus* was a single muscle in both cases, as described by Parsons. It did not, however, arise by tendon, as was the case in the other cavies which he examined. The *adductor mass* was in *Dolichotis* divisible into three strata, which could not, however, be said in any way to correspond with those of human anatomy. The largest sheet arose from the lower part of the symphysis pubis and the ramus pubis, and was inserted into the lower end of the shaft and inner condyle of the femur. The second part arose above and in front of that just mentioned, and was inserted into the lower half of the linea aspera. The third part was a small muscle lying behind the second, and inserted into the femur not far from the lesser trochanter. In *Dasyprocta* I found the two layers described by Mivart and Murie. The *Psoas* and *Iliacus* in *Dolichotis* consisted of two parts: (a) arose from the bodies of the lower lumbar vertebræ and from the anterior aspect of the upper part of the sacrum, and formed below a distinct

Y-shaped tendon, which was inserted by one horn into the lesser trochanter, and by the other into the inner side of the femur at about 1 cm. distant from the trochanter. This part of the muscle was separated by the nerves forming the lumbar plexus from (b), which was external to and larger than it. This part arose from the transverse processes of all the lumbar vertebræ and from the ventral surface of the ala of the ilium, and was inserted by a single strong tendon into the lesser trochanter deeper than the first-named part. In *Dasyprocta*, the muscles were arranged as in man. In *Dolichotis*, the outer head, and in *Dasyprocta* both heads, of the *gastrocnemius* possessed fabellæ. In both forms the *soleus* arose from the fibula only by a small flat tendon, and was inserted separately into the upper aspect of the posterior part of the os calcis; and *plantaris*, which was a separate muscle, sent its tendon to the heel-cap, and formed the main origin of the fibrous flexor brevis digitorum. *Tibialis anticus* had in both the double origin described by Beddard and Parsons. *Extensor longus digitorum* gave in *Dolichotis*, on one side, one tendon to the outer toe and two each to the middle and inner; on the other, it was distributed as in Beddard's specimen, that is, two tendons passed to the middle toe, and one to each of the others. In *Dasyprocta* it ended in a tendon for each of the three toes. *Extensor proprius hallucis* was in *Dolichotis* a very minute muscle, and passed, as Parson states, to the inner digit, where it joined the tendon of the extensor longus digitorum. It was a stronger muscle in *Dasyprocta*. *Extensor brevis digitorum* ended in both animals by two tendons, one for each of the two inner digits. Both forms possessed *peronei longus* and *quarti digiti*, as described by Beddard, and Mivart and Murie. The fibrous representative of *flexor brevis digitorum* ended in *Dolichotis* by forming three slips, one for each of the toes; in *Dasyprocta* it behaved in a similar manner on one side, on the other it supplied two of the toes only. The *long flexors* were as described by Beddard in his specimen of *Dolichotis*. There were two *lumbricales* in my specimen of *Dolichotis*, though Beddard found only one in his.

The most noticeable features in connection with the musculature of *Dolichotis* appear to be the following:—(1) the very complete set of muscles for the pinna; (2) the presence of

two fabellæ in connection with the masseter; (3) the degenerate condition of supinator brevis and pronator quadratus; (4) the double insertion of the psoas. In *Dasyprocta* the condition of the digastric is perhaps the most interesting fact.

Mr Beddard points out that the myology of *Dolichotis* presents a number of differences from that of the Cavy, and thinks that on the whole it is nearer to *Dasyprocta* than to the porcupines, but that it differs from both in the reduction of the extensors of the manus and the peroneal muscles,—an opinion which may perhaps require revision, in the face of more recent observations. I have placed in the form of a table some of the chief muscles as they exist in the two animals with which this paper is concerned and the Cavy.

| | DOLICHOTIS. | DASYPROCTA. | CAVIA. |
|------------------------------|-------------------------|-------------------------|-------------------|
| <i>Splenius colli,</i> . . | Present. | Present. | Absent. |
| <i>Coraco-brachialis,</i> . | Upper and middle parts. | Upper and middle parts. | Middle part only. |
| <i>Brachialis anticus,</i> . | Outer head only. | Both heads. | Outer head only. |
| <i>Triceps,</i> . . . | Four heads. | Three heads. | Three heads. |
| <i>Flx. br. manus,</i> . . | Absent. | Present. | Absent. |
| <i>Peroneus brevis,</i> . | Absent. | Absent. | Present. |

From these facts it would appear as if *Dolichotis* occupied a middle position between *Dasyprocta* and *Cavia*; and it will be seen that it differs from both in possessing a quadriceps brachii, whilst each of the others has a triceps.

AN INVESTIGATION INTO SOME OF THE PRINCIPLES OF AUSCULTATION. By ALBERT A. GRAY, M.D. Glasgow.

(Continued from page 232.)

PART II.—B.

Changes in Quality of Sound conducted through the Lung.

HITHERTO differences in *intensity* of the auscultatory signs have been considered. It remains to investigate the differences in *quality* which occur when sound is transmitted through the lungs to the ear.

It is evident that in this part of the investigations the tuning-fork can help us but little: being a pure note, either entirely without audible partial tones, or very nearly so, there can be no change in the quality of the sound.

For the most part we must depend upon the voice and the respiratory murmur to represent compound tones and sounds. Of these two the voice is, *for the present purpose of investigation*, the more valuable, because we know exactly where it is produced and its acoustic characters; but there is some doubt as to the point of generation of the respiratory murmur.

The physician recognises four types of the thoracic voice,—the Normal Vocal Resonance; Bronchophony; Ægophony; and Pectoriloquy. The characteristics usually associated with each are:—

- (1) Normal Vocal Resonance. An indefinite humming or buzzing noise; the spoken words are not distinguishable.
- (2) Bronchophony. This is more intense than normal vocal resonance; the words are distinguishable; it is usually associated with increased vocal fremitus.
- (3) Ægophony. The voice is not quite so intense as in bronchophony, and is not associated with increase of

the vocal fremitus. The sound is high-pitched, with a very pronounced nasal twang. Laennec compared it to the voice of Punch (*l'Auscultation médiate*, tome i. sec. 154).

- (4) Pectoriloquy. In this type the characteristic feature is not so much a difference in the quality of the musical part of speech, but a remarkable distinctness of the consonants. Usually the patient is told to whisper, in order that the vowels may not overpower the consonants. It is usually heard over phthisical cavities, when bronchophony may also be heard if the patient speak in the ordinary voice.

What are the causes of these changes in quality? In the first place, it is evident that if the investigation is to have any scientific value, the acoustic character of speech must be borne in mind. The works of reference which the writer has used for this purpose are Helmholtz' *Tonempfindung*, chapters v. and vi., 1870; and Gavarret's *Audition et Phonation*, pp. 310-400, 1877.

Normal Vocal Resonance.

On page 215 of this paper it will be seen that, in the writer's opinion, Skoda was justified in assuming that a certain amount of resonance or reinforcement of sound would occur in the trachea and bronchi. In considering alterations in quality, it appears that this statement will be fully justified, but in a way exactly the opposite of that which Skoda meant.

When phonation occurs, there is no doubt that the sound will pass downwards into the chest, both by the walls of the respiratory tract and by the air enclosed in those structures. The question at issue is, to find out to what extent the sound occurring in these two media reaches the stethoscope. Skoda maintained that the vibrations which occurred in the air were finally transmitted to the tissues, and thence to the stethoscope; while Laennec and most physicians nowadays hold that chiefly the sounds occurring in the walls reach the instrument.

It appears to the writer that there can be no doubt that vibrations pass to the parietes by both media, though to a varying extent, both in health and disease.

In health it is very plain that any sound occurring in the air in the bronchi, bronchioles, and alveoli will, without much difficulty, pass into the tissue, because the healthy lung is such an exceedingly *light*, delicate structure, easily set in vibration by a sound occurring in the air which is in contact with it. From the parenchyma the sound will easily pass into the stethoscope.

Similarly, vibrations conducted downwards by the walls of the respiratory tract will pass by the walls of the bronchioles and alveoli to the instrument, provided of course that these structures are tense.

To what extent do these two sets of vibrations contribute to the normal vocal resonance? It would be impossible to say accurately; but it appears to the writer that the reason why the normal thoracic voice is so indefinite, and of a buzzing or humming character, is, that all that part of the sound which has passed down by *the air* has become confused in its course by constant reflection. It is a well-known fact that the voice becomes rapidly confused and indistinct if it be passed through a tube with elastic or rigid walls; the reason being that the consonants or articulate parts of speech become overpowered by the more musical or continuous parts, because of reflection of sound or reverberation.

Normal Respiratory Murmur.

Before considering changes in the quality of the respiratory murmur, it is necessary that the point of origin of that sound be discussed. In regard to this point, the theory most in vogue at present is, that the normal respiratory murmur occurs at those points where the bronchioles open into the infundibula (Fagge and Pye-Smith, *op. cit.*, vol. i. pp. 935 and 936; Bristowe, *op. cit.*, p. 387). A few physicians, however, hold that the normal respiratory murmur is produced at the larynx, and conducted to the stethoscope through the lungs.

There are some serious objections to the hypothesis that this murmur is produced in the infundibula.

(1) It has never been shown that the passage of an exceedingly minute quantity of air from a minute tube (.5 mm. diameter,—M'Kendrick, *op. cit.*, p. 299) into a minute cavity really does produce a sound at all. The amount of air actually

passing in and out of each infundibulum during the inspiration and expiration must be exceedingly little, because the whole contents of an infundibulum is very small, and the differences in the cubic space during expiration and inspiration must be far smaller still, because there is no approach to collapse of the structure during expiration. Could, then, these exceedingly minute quantities of air really produce a sound in the infundibula of such intensity that, even summed up together, the result would be audible at the thoracic wall? To the writer it appears highly improbable that they could, and most certainly it has never been shown that they do. Therefore the present theory has to *assume* that a sound occurs at all,—an assumption which has no basis in fact. This objection is a very serious one.

(2) The theory in question totally fails to explain the occurrence of the expiratory portion of the respiratory murmur. That is to say, even if the inspiratory portion were accounted for by assuming that a fluid vein in the infundibulum produced the sound, there is no fluid vein at all during expiration. Fagge (*op. cit.*, vol. i.; *op. cit.*, p. 936, footnote) suggests that the bronchiole may project into the infundibulum and form a rim. Now, there is no evidence at all, either anatomical or other, for supposing that such a condition exists; and even if it were the case, there is no proof that such a structure could produce a sound during expiration.

(3) It is a well-known clinical fact, and was pointed out by Stokes long ago (Pye-Smith and Fagge, *op. cit.*, vol. i. p. 936), that when the larynx is diseased it is often difficult or impossible to tell by auscultation if the lung is healthy or affected. Now, if the normal respiratory murmur depended upon the formation of a fluid vein in the infundibula, it is difficult to see why it should be altered by changes at the larynx (dyspnoea is understood to be absent).

(4) The experiments upon which in great part this theory rests are open to quite other interpretations than those put forward by the supporters of the theory. These experiments were performed by Bondeau, Bergeon, and Chauveau, and are to be found in the *Gazette Hebdom.*, December 1863, Paris. The trachea of a horse was cut through and dragged out through the wound in the skin. On listening over the lungs the inspiratory murmur

was not diminished in intensity. From this experiment it was held as proven that the inspiratory murmur could not be produced at the larynx. It appears to the writer that there is this fallacy: the trachea could hardly be brought through a wound of such a nature without either being pinched by the edges of the wound, or being bent and narrowed at the point where it is turned out of its natural course before being brought through the wound. This sudden narrowing would produce all the requisite conditions for a fluid vein, so that the sound heard over the lung by the observers may after all have been a sound transmitted from the trachea.

Another experiment to which, perhaps, most importance was attached was as follows:—The pneumo-gastric nerve of a horse was cut through; on listening over the thorax and trachea respectively, the inspiratory murmur was found to have disappeared over the thorax, while the tracheal murmur remained. From this it was assumed that the muscular walls of the bronchioles were paralysed, and hence opened into the infundibula by wide funnel-shaped mouths, and no fluid vein was formed (Pye-Smith and Fagge, *op. cit.*, vol. i. p. 935). But there is another way of explaining this without any such assumption. By paralysing the muscles of the bronchi and bronchioles, *relaxation* of those structures would ensue, so that a sound carried from the larynx would be lost; in the writer's opinion this is exactly what does happen when the pneumo-gastric is cut.

(5) The auscultatory signs of emphysema throw a great deal of doubt upon this theory. In that disease the inspiratory murmur is greatly diminished, and may even be inaudible: is it to be assumed, then, that the bronchioles open into the infundibula by a *wide funnel-shaped opening*? If this be granted, the question next arises, How is the prolonged and undiminished expiratory murmur of emphysema produced? In the work just quoted (Fagge and Pye-Smith, *op. cit.*, vol. i. p. 936, footnote), and on the very next page to that just quoted, it appears that "in emphysema it is fair to suppose that the *mouth of the bronchiole projects some distance forwards into the space formed by the dilated air-sacs around it*"! That is to say, that the anatomical conditions of emphysema may be exactly the opposite of those

obtaining after section of the pneumo-gastric, and yet the effect of these conditions upon the inspiratory murmur is just the same,—a conclusion which is logically absurd.

(6) The following experiment which the writer performed throws considerable doubt upon the deductions drawn from the experiment just related. A dog was killed with chloroform, and its lungs carefully removed from the thorax. A small circular block of wood with a metal tube running through its long axis was tied tightly into the mouth of the trachea. On blowing through the tube and thus inflating the lungs, a loud sound was heard over the trachea, comparable to the tracheal murmur of ordinary inspiration. On listening over the lungs, however, a murmur was also heard during inflation, softer in character than that heard over the trachea, and quite comparable to the normal inspiratory murmur of health. Now, in this case the muscular walls of the bronchioles were certainly paralysed, for the lungs had been extracted from the body some hours before; therefore, according to the accepted theory, there can have been no fluid vein at the mouths of the bronchioles sufficient to produce a sound in the infundibula; but a murmur, loud and distinct, was heard over the lung parenchyma. It appears to the writer, therefore, that this sound was certainly transmitted from the trachea, just as, in his opinion, the normal respiratory murmur is.

(7) The following experiment, though not absolute proof, would lend support to the hypothesis that the normal respiratory murmur is produced at the larynx.

Into the mouth of a healthy living adult was inserted a short india-rubber tube and the lips closed round it, care being taken that the lumen of the tube was not obliterated by the pressure of the lips or teeth. The subject was instructed to breathe through the tube, and not through the nose. A tuning-fork (A 440 vibs.) was kept vibrating at a constant intensity by a battery and coil, and was held immediately opposite the opening of the india-rubber tube. On listening over the thorax the writer heard the sound distinctly, and it was very noticeable that it was considerably stronger during inspiration than during expiration; the cause of this difference being, that the current of air during inspiration helped to conduct the sound into the thorax,

while during expiration the current produced a reverse effect.

Now, it appears to the writer that the difference between the expiratory and inspiratory murmurs of normal respiration is capable of similar explanation.

During *inspiration* a fluid vein is formed below the glottis, and sound passes downwards by the air, and also by the walls of the trachea, etc. Not only so, but the current of air is passing downwards towards the parenchyma, and this will aid the propagation of the sound in that direction. On reaching the parenchyma, the sounds find it of exceedingly slight density, and hence easily set in vibration, the latter being conveyed to the parietes as related above, and to a certain extent reinforced by the sound which has been carried down the whole way by the walls of the trachea, bronchi, etc.

During *expiration* a fluid vein is formed above the vocal cords. So far as the vibrations which are conducted by the walls of the trachea, etc., are concerned, there will be little difference between inspiration and expiration; but as regards the sound which is to pass downwards by the air, a different state of matters obtains. First of all, the fluid vein is produced above the cords, and not below, which entails a certain amount of loss; but what is of more importance is, that the whole force of the current of air is directed away from the parenchyma. This causes a still greater loss of the sound transmitted downwards by the air. Thus it will be seen that the aerial vibrations which reach the parenchyma during expiration will be either greatly enfeebled or entirely lost; the expiratory portion of the respiratory murmur will therefore be composed chiefly of the sound conveyed down by the walls of the respiratory tract. For that reason the inspiratory murmur will be much louder than the expiratory.

It will be asked, why is the expiratory murmur not only so much fainter, but also much shorter than that of inspiration? The explanation is as follows. If the physician listen over the larynx of a healthy subject, he will notice that though the murmurs of inspiration and expiration are equal in duration, they are different in character. The inspiratory murmur is of continuous intensity throughout, but that of expiration, though at its commencement as strong or possibly stronger than the inspiratory

sound, becomes more feeble towards the close of the act. This is, of course, what we would expect. Inspiration being a muscular act of continuous intensity, it follows that the flow of air through the glottis will be kept at a constant rate. But expiration is not a muscular act; it is due to the elasticity of the thoracic walls and pulmonary tissues; hence it is evident that the expiratory force must decline from the beginning of the act to the end; the result of this is, that the air is driven through the glottis with diminishing force, and hence the murmur produced becomes less intense as the act proceeds.

If the experimenter listen over the chest of a healthy subject who has been told to make a muscular effort during expiration, and keep the force of the expiratory act at the same intensity throughout, he will find that both parts of the inspiratory murmur are of equal duration, or very nearly so. Indeed, there is no need to cite experiment in this matter; disease itself offers an example. In emphysema, where expiration is a muscular act, the two portions of the respiratory murmur are of equal duration, or the inspiratory portion may even be shorter than the expiratory.

Now, having shown that the murmur of expiration as heard over the trachea becomes enfeebled towards its close in the healthy subject, we can see at once that if any part of that murmur is to be lost during its propagation to a distance, it will be that part which occurs at the end of the act. *This is exactly what we find on listening over the thoracic walls;* the expiratory murmur begins at the moment of expiration, but dies away long before the act has reached its close.

The reason why the healthy thoracic murmur is softer than that heard over the trachea and bronchi, is the same as that which was previously described to account for the buzzing, indefinite nature of the thoracic voice. By propagation downwards through the bronchi, etc., the musical elements of the sound gradually overpower the harsher elements, with the result that the sound becomes softer and more continuously musical in character.

It may be urged against the explanations just put forward that the voice is produced during expiration, and that, as a result, very little of the sound will be transmitted downwards

by the air, just as happens during the expiratory murmur. There is this difference, however: the voice is far more intense than the expiratory murmur, and can easily cope with the current of air passing upwards.¹

Bronchophony.

As in health, so also in consolidation the voice is transmitted downwards both by the walls of the respiratory tract and by the air contained in them. In their passage downwards, according to Skoda, the aerial vibrations are reinforced as soon as the voice reaches those bronchi which are surrounded by condensed lung, with greater intensity than in health. This is doubtful, but for the present let it be assumed as true. One thing, however, is quite certain: any vibrations occurring in the air within those tubes surrounded by condensed lung can only with enormous loss in their intensity become transformed into vibrations in the solid, dense organ. Every acoustician will agree on that point. On the other hand, it has been shown that the healthy lung could easily be set in vibration by sounds transmitted down by the air because of its slight density. It follows, that in consolidation very little of the sound occurring in the air of the bronchi and bronchioles ever reaches the stethoscope compared to that which does in health. This is the reason why the thoracic voice heard over consolidated lung is not so indefinite as in health; the confusion of sounds which occurs in the passage of the voice within the tubes is not permitted to reach the ear because of the great mass of dense lung which intervenes. On the other hand, the sounds which are conducted by the solid tissues are conducted with far greater intensity than in health, for the reasons given on pages 217 and 218, viz., increased tension and increased density and homogeneousness. This is the reason why bronchophony is not only more intense, but more distinct and articulate than the healthy thoracic voice.

¹ Since writing the above pages, the writer has become aware of the fact that an explanation of the normal respiratory murmur similar to that just given has in recent times been taught in Germany. *Vide* Vierordt's *Text-Book of Medical Diagnosis*, p. 142, 1891; trans. by Stuart. But what the actual acoustical reasoning which led to this explanation is, the present writer has not been able to find out.

Bronchial Breathing.

From the explanation of bronchophony just given, the cause of bronchial breathing will easily be inferred. Just as the articulation of the voice is not sufficiently diminished by resonance to prevent its being perceptible, so also the harshness of the respiratory murmurs is not softened by reverberation in the tubes, but is conducted down by the walls of the bronchi and solid lung, etc.

The *inspiratory portion* of the murmur of bronchial breathing is not necessarily more intense than the same portion of the normal respiratory murmur. The reason of this is, that in health such a very large portion of the sound is carried by the air. Now, in condensation, all or nearly all this sound is lost so far as the ear is concerned, and the increased intensity of that part of the sound conducted by the walls of the tubes may or may not be sufficient to make up for the loss of sound originally aerial.

The *expiratory portion* of the murmur of bronchial respiration is, on the other hand, always longer and more intense than in health: the reason of this, of course, is, that even in health comparatively little of the sound is carried by the air; and though that may be lost, it is far more than equalled by the amount gained by increased conducting power through the walls of the respiratory tract and condensed tissue of disease. This increase, as before stated, is due to the increased tension and homogeneousness of the tissues.

Tubular, amphoric, and cavernous are variations of bronchial breathing, all agreeing in this respect, that the inspiratory and expiratory portions are equal in intensity, or nearly so. It may be that in certain cases some amount of resonance in cavities occurs, and produces what is known as cavernous respiration. That this is not always so is proved by the fact that cavernous respiration may be heard where no cavity exists (Fagge and Pye-Smith, *op. cit.*, vol. i. p. 936). The writer is inclined to believe that these variations are due to the purity and intensity with which the sounds are carried away from the walls of the bronchi and trachea, *e.g.*, if extreme tension exists between the thoracic

walls and a large bronchus, such as very frequently occurs in the case of cavities (see page 222), then the breathing will approach most nearly to the tracheal in character.

Pectoriloquy.

This is merely an exquisite example of bronchophony, and most writers look upon it as such. It bears out completely the explanation of the normal vocal resonance and bronchophony given in the previous pages.

The patient is told to whisper. Why is this done? Because by so doing the musical parts of speech are enfeebled, and even the slight resonance which probably takes place in the trachea when bronchophony occurs is very much diminished, and the ear hears the voice almost as distinctly, though not so loudly, as at the larynx. The conduction of sound by the solid tissues is most complete in pectoriloquy, and the conduction by air is almost completely in abeyance so far as the ear is concerned; the result is that less confusion of sound results than in any other condition.

That the presence of a cavity is not necessary for the development of pectoriloquy is proved by the fact that it is sometimes most perfectly heard over a lung in which no cavities exist at all. (Fagge and Pye-Smith, *op. cit.*, vol. i. p. 939. Bristowe, *op. cit.*, p. 392. Finlayson, *op. cit.*, p. 639.)

It appears to the writer that the cause of pectoriloquy is excessive tension between the root of the lung and the pleura; this is what is exceedingly likely to occur in phthisis which has reached the stage of excavation, but it is quite conceivable that such a degree of tension might exist before that stage (see page 222), or sometimes even in pneumonic consolidations.

From the explanations of normal vocal resonance, bronchophony, bronchial breathing, etc., just related, it will be seen that we are in the further position to explain other phenomena, which, so far as the writer is aware, are inexplicable by any other theory. Physicians know well that bronchophony may vary in intensity and also in clearness. Now, it has been shown, in the first part of this paper, that variations in the

intensity of the voice are due chiefly to variations in the tension of the structures, and it is needless to enter further into that subject here.

The explanation of variations in distinctness of the voice appear to the writer to be as follows:—It has been shown that as the aerial vibrations are conducted downwards, they are reflected in the tubes, with the result that confusion of the sound occurs; and it is plain that the further this reflection goes, the more complete will be the confusion. Thus the confusion will be least in the trachea, and become more pronounced as the sound passes downwards.

It has been shown, further, that when consolidation occurs, the amount of sound transmitted from the air to the solid tissues becomes enormously diminished. It follows, then, that the more nearly the consolidation approaches the larger bronchi or trachea, the less do these aerial vibrations take part in the sound which finally reaches the ears, and hence the voice is more articulate.

In practice we can never quite eliminate the aerial vibrations, because the trachea is never surrounded by consolidated tissue; so that the walls of that structure, at least, are always ready to take up sound from the air in its cavity, the more so in that they are elastic.

Illustrations of the effect of resonance or reverberation upon a series of articulate sounds quickly following one another are very common on a larger scale in Nature. If one listens at the mouth of a long tunnel while a railway train enters at the other end, at first one hears a low, continuous, loud sound, the constituent parts of which the ear cannot distinguish. As the train comes nearer, however, the sound becomes harsher, then rougher; gradually the rattling of the carriages (especially if it be a goods train) becomes distinguishable from the rest of the sound, and finally the individual puffs from the engine. The reason of these elements of the sound becoming clearer as the train approaches is not merely a matter of increased intensity of the sounds; for if the train be moving in the open air, the different elements are distinguishable further off than they are when in the tunnel, although in the latter case the sound is far more intense. The reason of the gradually increasing clearness is, that as the train

approaches, the sound has to undergo less reflection before it reaches the ear.

On the other hand, the clearness with which sounds may be conducted if they do not undergo reflection in a closed space is sometimes exemplified in an astonishing manner. On the New Year's eve of 1896, the writer was standing upon the shore at Strone, Argyllshire. At Hunter's Quay, on the other side of the loch, a distance of nearly a mile, a company of revellers were singing. Every syllable of the song ("For he's a jolly good fellow") was distinguishable as it came across the sea. When the song was finished, ordinary conversation apparently ensued amongst the company. The exact words could not be made out, (except occasionally such words as "pipe"); but the words and even the syllables were distinguishable from one another. The writer has repeatedly observed the remarkable clearness with which sounds were transmitted across the loch on calm, quiet evenings, but never in such perfection as on that occasion. It should be remarked that on the evening mentioned there was a slight mist in the air and a dead calm upon the sea.

It appears to the writer that we have similar examples in the chest: there is this difference, however, that we hear the sound through solid tissues. In health the sounds of the voice and of respiration are carried downwards from the larynx, both by the air in the tubes and by the walls of the respiratory tract. It is evident that the part of the sounds carried by the air is reflected again and again, and thus becomes confused, continuous, and softer. Further, the portion of the sound can be transmitted to the parenchyma without much difficulty *in health*, because the tissue in that condition consists of exceedingly light stretched membranes. Hence the sound which reaches the stethoscope is confused and softened: this applies both to the voice and the respiratory murmur.

When *consolidation of the lung* occurs, no doubt the sounds conducted downwards by the air are resonated or reflected just as much as in health, and possibly more so; but they do not reach the stethoscope in anything like the extent to which they do in health. The tissue is now converted into a heavy, solid mass, only with the greatest difficulty set into vibration by sounds occurring in the air, though easily caused to do so by

sounds reaching it through the solid structures, just as a heavy plate of iron may be set strongly into vibration if the stem of a tuning-fork be brought *into contact with it*.

The sounds conducted down by the walls of the trachea and bronchial tubes will easily set the solid condensed mass into vibration, because the densities of the walls of the bronchial tubes and the hepatised lung are nearly the same. Now, as these vibrations have not undergone much resonance or reflection, it is evident that the sounds will be similar in character to those heard over the main bronchi. The vocal resonance will be articulate, and the respiratory murmur harsh; the expiratory and inspiratory portions being of nearly equal duration.

From the explanations offered by the writer to account for alterations in clearness of sound transmitted through the lung, and also from his explanations on the causes of alterations in intensity of sound transmitted through those organs, it might be expected that over the site of a collapsed lung faint bronchophony and bronchial breathing might be heard. That is to say, that the thoracic voice and breath-sounds, though fainter than in health because of the diminished tension, would approach more nearly in character to the tracheal or bronchial voice and bronchial respiration than in health, because the sound which reaches the ear has undergone less resonance (as explained part ii., A). Many authorities state this as a fact, and thus bear out the writer's views to the full; but the writer must admit that he has not heard either bronchophony or bronchial respiration over a collapsed lung; the reason being that the diminution of tension causes such a great loss of sound that the remainder which reaches the ear is so very faint, its quality cannot be easily compared to bronchophony or bronchial respiration as heard over a main bronchus. This, of course, only alludes to the cases in the writer's own experience. No doubt, faint bronchial breathing and faint bronchophony may sometimes be heard over a collapsed lung; but if these are perceptible, they will be fainter than the normal vocal resonance or normal thoracic respiratory murmur, because of the diminution of tension.

Ægophony.

This change in the vocal resonance is acoustically the most interesting and most peculiar alteration of the thoracic voice. Not only so, but this acoustic peculiarity, as will be shown later, enables us to assign to ægophony its causation with a considerable degree of certainty.

Ægophony is not necessarily a change in the intensity of the normal vocal resonance; it is usually more intense than the latter, but not always. Neither is it a change in the distinctness of articulation.

The outstanding features of ægophony are:—(1) it is higher-pitched than any other form of the thoracic voice; (2) it is nasal; in its typical form, very nasal. Besides these characteristics, it is tremulant.

Now, since the sound is higher in pitch than it normally should be, it is evident that one of two things must occur: either the lower tones of the voice must be diminished in intensity, or the higher tones must be increased.

But, besides being high-pitched, ægophony has another characteristic, more prominent perhaps than its pitch, viz., its *nasal character*. How is this nasal character to be accounted for?

Fortunately, acoustics is a more or less exact science, and vague generalities are of no value. There is one way in which a sound may become nasal, and, so far as the writer knows, one way only; that is, by being possessed of a *preponderance of the inharmonic or uneven series of upper partial tones*.

The writer would like to make a digression on this subject.

Many authors writing on the subject of ægophony state that the sound is due to a preponderance of harmonic partial tones. (Bristowe, *op. cit.*, p. 393. Gibson and Russell, *Physical Diagnosis*, 1890, p. 160.) But no preponderance of harmonic over-tones could make a sound nasal. Similarly, the statement that ægophony is due to the preponderance of over-tones in general is incorrect, because this also would not give the voice a nasal tone. On the other hand, to quote Helmholtz:—"If only the uneven (that is, inharmonic) partials are present . . . the quality of the tone is hollow; and when a large number of such upper partials

are present, nasal" (*Tonempfindung*, 3rd edition, 1870; trans. by Alexander J. Ellis, p. 173.)

There is, therefore, no question but that the nasal tone of ægophony—or as Laennec expressed it, like the voice of Punch (*L'Auscultation médiate*, tome i. s. 154)—is due to a preponderance of the inharmonic upper partial tones. It is this fact which, as will be shown later, enables us to assign to ægophony its true cause with certainty.

Before going on to give his own explanation of ægophony, the writer would like first of all to criticise the presently accepted theory. This is necessary, as that hypothesis is very widely accepted. This theory was elaborated by Dr W. H. Stone, and is enunciated in *St Thomas's Hospital Reports*, 1871, vol. ii. p. 187. It is to this effect: that the voice passing from the lung into the fluid, through the fluid, and again from the fluid into the parietes, undergoes a certain amount of loss. In this transmission the lower or fundamental tones suffer more than the higher or partial ones; hence the voice reaches the ear higher in pitch, and ægophony is produced. Thus the hypothesis is very simple, and it is perhaps on this account that it has been so widely accepted. But when carefully examined, it is found to be incompetent to explain the facts, and the objections to it are numerous.

(1) If ægophony be due to a greater loss of the lower tones than the upper ones, then it would of necessity be a very faint sound, because the fundamental tones are the strongest element of the voice. Besides, although the lower tones may be lost more in proportion, it is evident the partials must also be lost to a certain extent. This would make ægophony an exceedingly faint sound. As a matter of fact, it may be and usually is more intense than normal vocal resonance.

(2) The theory does not explain the great preponderance of the inharmonic partials; because no loss of tones by mere transmission through various media would allow the inharmonics to pass, and the fundamentals and harmonics to be stopped. Thus the prominent feature of ægophony is absolutely unaccounted for, viz., the nasal tone.

(3) So far as the transmission of sound through a homogeneous fluid is concerned, it has been proved that the lower

tones do not suffer so much loss as the higher:—"sehr eingehenden studien von Warburg (Magnus) über die Verbreitung von Tönen durch Flüssigkeiten, sondern vielmehr nachweisen dass die tiefen Töne besser hindurchgehen als die hohen (Niemeyer, *Handbuch der theoretischen und clinischen Percussion und Auscultation*, 1871, ii^{te} Band, ii^{te} abtheilung, p. 55).

The writer has experimented on this subject himself, and can fully bear out that statement. So that even if the lower tones did lose proportionately more in transmission from solid to liquid, and *vice versa*, they would lose less in the actual transmission through the fluid.

(4) The experiment upon which this theory was elaborated was not properly appreciated. It was as follows:—An assistant spoke into a wide india-rubber tube over which was placed a bladder filled with water. The experimenter listened with a stethoscope on the upper surface of the bladder and heard ægophony (*St Thomas's Hospital Reports*, 1871, vol. ii. p. 189; and Fagge and Pye-Smith, *op. cit.*, vol. i. p. 940). From that experiment was drawn the theory under discussion, viz., that the lower notes were intercepted and the higher ones allowed to pass.

The writer has repeated this experiment, and has found that the facts are perfectly true. The originator, however, neglected to take into consideration one very important fact,—the fluid was enclosed in a bladder, that is to say, a stretched membrane. The following experiment which the writer performed shows the importance of this:—

If an india-rubber tube be led into water and out again so that no water gets into the tube, and the ear be applied to the outside of the vessel, not a trace of ægophony will be heard, no matter how thin or how thick the layer of fluid be between the ear and the india-rubber tube. The truth, of course, is that the ægophony heard by Dr Stone was due to the walls of the bladder. The layer of fluid was only a secondary matter.

In the same way Laennec was able to obtain ægophony by interposing a bladder filled with water between the stethoscope and the interscapular space of a healthy individual.

(5) Ægophony may be imitated without any layer of fluid at all. Skoda produced it by speaking while a disc was placed

between his teeth and lips (Skoda, *op. cit.*, p. 71). An excellent way of imitating the sound is with the well-known comb-and-paper experiment.

(6) The present theory in no way explains why ægophony disappears as the lung goes on to complete collapse, nor why it is heard so much better near the angle of the scapula and below the axilla.

There are many other objections to this theory, but space forbids of their enumeration.

Having shown that the theory of ægophony at present in vogue is untenable, it remains to find out an explanation which will account for the facts.

The inharmonic series of upper partial tones are readily resonated by various media,—plates, discs, stretched membranes, etc. (Helmholtz, *Tonempfindung*, trans. by Ellis, pp. 114–120).

In the chest there are certainly neither plates nor discs, but it is interesting to observe that Skoda made use of the disc to imitate ægophony (*Auscultation and Percussion*, 4th edition, trans. by Markham, p. 71). It is improbable that Skoda knew why the use of a disc placed between the lips and teeth should produce the phenomenon, because Helmholtz's great work was not published at that time. It is easy now to see the reason: the disc resonated in sympathy with the inharmonic partials of the voice.

In the chest, however, we may, under certain circumstances, find a stretched membrane in such a condition as to admit of its resonating in sympathy with the inharmonic partials; and the writer will now proceed to show how this may happen.

Into the mathematical and theoretical aspect of the question it is obviously beyond the scope of this paper to enter. That subject is fully discussed in Lord Rayleigh's *Theory of Sound* (1877, vol. i. pp. 250–292). One law, however, must be noted: a stretched membrane can only vibrate in unison with sounds higher than its own proper tone, and not with those which are lower. This was at one time disputed, but it has been shown to be true (Lord Rayleigh, *op. cit.*, p. 290).

Before passing on to show how a suitable stretched membrane occurs in the chest, it is worthy of note that most imitations of ægophony have been made through the medium of stretched

membranes:—Laennec: the bladder filled with water placed over the interscapular region of a healthy chest; Stone's case of the bladder filled with water placed over an india-rubber tube; the well-known experiments with the comb and paper,—all these are examples of stretched membranes. Skoda's disc between the teeth and lips is not an example of a stretched membrane, but was another way of resonating the inharmonic partials. No writer has imitated ægophony by means of stretched strings, for the very good reason that these vibrate in sympathy with the harmonic partials (Helmholtz, *op. cit.*, p. 71). All these experiments give further proof of the correctness of the writer's statement that ægophony owes its character to a preponderance of inharmonic partials.

Since the present theory of ægophony cannot be held correct for the reasons just stated, the following explanation is offered:—

In health the sound of the voice is transmitted downwards until it reaches the pleura: fundamental tones, harmonic partials, and inharmonic partials. Now, the pleura is a stretched membrane, and would resonate in sympathy with the inharmonic partials were it not that it is firmly held up against the parietes by atmospheric pressure. Hence we do not get a nasal twang in health.

In pleurisy, however, the visceral pleura, instead of being held up against the thoracic wall, is in contact with a fluid which will allow it to vibrate in any mode of vibration peculiar to itself. But the effusion of fluid into the pleural cavity causes collapse of the lung which lies beneath; and when this occurs, the visceral pleura cannot in any sense be called a stretched membrane,—it has become relaxed and wrinkled. At the upper margin of the fluid, however, where the layer is becoming very thin, it is evident that the pleura cannot be completely relaxed; so that at this part of the chest we have the requisite conditions for the resonance of the inharmonic upper partials and the production of ægophony.

But it is not to be assumed that this part of the pleura will always be in a condition to resonate sufficiently in order to produce ægophony. It might be too small in extent. There is one part of the lungs, however, at which the requisite conditions will be much more perfectly developed than at any other part;

that is, at the interlobar septum, because at this structure a whole lobe might be collapsed and retracted, while that above it remained quite distended. An excellent specimen demonstrating this condition will be found in the Pathological Museum of the Western Infirmary, Glasgow (Series III. No. 19). It is therefore evident that in this region, and under these conditions, ægophony will be most likely to occur, and most perfect when it does occur. Let us see, then, what parts of the thoracic wall correspond to the interlobar septum.

On the *left side* the septum passes from the transverse process of the 4th dorsal vertebra, crosses obliquely the 4th interspace and 5th rib, and reaches the 5th interspace in the axillary line; it then crosses to the 6th interspace, and passes forward in that space. On the *right side* the septum begins at the transverse process of the 5th dorsal vertebra, and passing obliquely downwards, reaches the 6th interspace at the angle of the scapula, and runs forward under the 7th rib. The septum on the right side, separating the middle lobe from the upper one, does not reach the posterior aspect of the lung, but branches off from the main septum and runs forward. (These descriptions were taken from a model in the Anatomy rooms of Glasgow University.)

Further, the inferior surface of the upper lobe on the left side, and of the middle lobe and posterior part of the upper lobe on the right, look obliquely backwards and downwards. The angle of the scapula lies on the 6th interspace and the 7th rib (*Quain's Anatomy*, 8th edition, vol. i. p. 81). In the position in which the back of a patient is usually examined, however, the angle of the scapula is carried forwards and slightly upwards, so that it comes to lie upon the 6th rib rather than on the 7th.

From this it will be seen that the interlobar septum passes close to the angle of the scapula; on the right side, indeed, it may be said to run just beneath it; and as the lower surfaces of the upper lobe on the left side and of the middle lobe and posterior part of the upper lobe on the right side look backwards as well as downwards, there is every requisite for the production of ægophony in the region about the angle of the scapula and the neighbouring region of the axilla.

It is just at these parts that ægophony may be heard in its most perfect development; indeed, one writer goes so far as to say that it is never heard in perfection anywhere else (Bristowe, op. cit., p. 393).

It will be asked why ægophony is not heard typically just below the interlobar septum, between the scapula and the spine, if the explanation just given be correct. The reason is, that in this position bronchophony, or strong vocal resonance, is usually heard both in health and disease. The result of this is, that the strong fundamental tones normally heard over this area disturb that relationship between those tones and the inharmonic partials, with the result that ægophony is not typical. Still, even here a considerable nasal twang is not uncommonly heard in pleurisy.

The fact that ægophony is high-pitched is explained by the law that a stretched membrane resonates in sympathy with tones higher than its own proper tone, but not with those that are lower. It is evident, then, that the lower tones of the voice will not be resonated, while the upper ones are, and hence the pitch will be raised.

The trembling that accompanies ægophony seems to be due to quivering in the fluid, which would alter momentarily the condition of the stretched membrane in contact with it, making that membrane now lax and now tense.

There is also, no doubt, a certain amount of loss of the lower tones and partials by transmission from the pleura through the fluid and to the parietes. This loss may even be sufficient to produce a perceptible diminution of tactile fremitus at the place where ægophony is heard, but it certainly does not always do so.

The explanation of ægophony above given accounts for several facts which are quite unexplained by the present theory :—

- (1) The preponderance of inharmonic partials.
- (2) The peculiarly limited position over which ægophony is usually heard.
- (3) The fact that the phenomenon disappears when the effusion becomes very great: the lung being totally collapsed, no stretched membrane remains.
- (4) This explanation also accounts for the fact, that although

the lower notes are diminished rather in ægophony, yet the sound as a whole is more intense usually than normal vocal resonance: the greatly strengthened inharmonic partials more than counterbalance the somewhat enfeebled lower tones.

It might be objected to the writer's explanation, that the pleura with the alveoli below is too thick to be termed a stretched membrane. This, however, is merely a matter of names; if preferable, the term 'elastic surface' might be employed. Both of these possess one feature in common—the power of resonating, particularly in sympathy with the inharmonic partials.

Although ægophony is most usually met with at the regions before mentioned (the angle of the scapula and adjacent part of the axilla), yet its area of distribution may be much larger.

Laennec records several such cases, and in two of them he had the opportunity of post-mortem examination. In both of these he found that the lung had been prevented from collapsing by numerous adhesions. He attributed the presence of ægophony in these cases, as he did in others, to the fact that the layer of fluid was only of slight thickness. It seems to the present writer that in these cases the pleura formed a stretched membrane of considerable extent, as it was prevented from collapsing and becoming relaxed (*Traité de l'Auscultation médiate*, 1837, tome i. p. 93).

In rare cases of pneumonia the voice is sometimes ægophonic, or at least accompanied by an ægophonic twang. This is probably due to the presence of fresh pleuritic exudation which not uncommonly accompanies pneumonia. This exudation, though not absolutely liquid, is jelly-like, and very vibratile, and would easily permit the elastic surface beneath to vibrate in a manner peculiar to itself,—that is to say, in sympathy with the inharmonic partials.

The Respiratory Murmur of Emphysema.

In discussing the physical causes of the normal respiratory murmur, the writer gave his reasons for believing that that sound is generated at the larynx, and is conducted through the lungs to the parietes. It is not necessary, therefore, to go

over exactly the same ground in regard to the point of origin of the respiratory murmur of emphysema, for the arguments in favour of considering the normal respiratory murmur to be generated at the larynx apply equally, or even more forcibly, to the respiratory murmur heard in emphysema.

The cause of the alteration in quality of the respiratory murmur in this disease appears to the writer to be as follows. The movements of respiration are altered in emphysema. Expiration, instead of being accomplished by the elasticity of the thoracic walls and lung-parenchyma, is difficult, and attended with muscular effort from the beginning of the act till the end, and the act as a whole is prolonged. Inspiration, on the other hand, is no longer attended with the muscular effort which is associated with it in health: the thorax is naturally in the position of inspiration, and springs quickly back to that condition when the action of the expiratory muscles ceases. From these facts, it is plain that corresponding changes must occur in the respiratory murmur heard over the trachea. The expiratory portion of the sound is greatly prolonged, while the inspiratory is much shorter than in health. Now, this being the condition of the respiratory murmur over the trachea, it follows that a similar condition will obtain over the thoracic parietes. This is what is found to be true. The inspiratory portion of the murmur is shortened, while the expiratory portion is prolonged.

As regards the intensity of the respiratory murmur in emphysema, as a whole it is greatly diminished, this being due, as was pointed out on page 225, to the diminution of tension which occurs in the lungs in that disease. Emphysema offers another support to the view that the normal respiratory murmur really takes place at the larynx, and is conducted to the thorax by the lungs. Supposing that the normal inspiratory murmur occurs in the infundibula, and that in emphysema this sound is greatly diminished because the conditions for its production are unfavourable, the cause of the greatly diminished vocal resonance and fremitus still remains quite unexplained, as the voice is certainly not produced in the infundibula. On the other hand, if the normal respiratory murmur be generated at the larynx, there is no need to seek further for a cause to account for its diminution in emphysema. The loss of tension fully accounts

both for the great diminution of vocal resonance and fremitus, and also for the diminution in intensity of the inspiratory murmur.

SUMMARY.

The results of experiment and observation in this paper may be summarised as follows:—

Intensity of vocal resonance, vocal fremitus, and the breath-sounds.

The *intensity* of the sounds taken, without regard to differences in quality, depends chiefly upon the tension which exists in the structures of the organs of respiration. With increased tension, there will always be increased intensity of the auscultatory signs, though there may be no alteration in quality. Thus in childhood, or in an organ which, though healthy, is suddenly called upon to do compensatory work, the respiratory murmur is louder than in the healthy adult.

In individuals the loudness of the vocal resonance and respiratory murmur may vary within wide limits, even in health, because the tension in the structures varies in the same proportion. In those who are passing into the later registers of life, the auscultatory signs are apt to become diminished in intensity, because the tension in the respiratory organs is liable to become diminished with age.

In emphysema the auscultatory signs are diminished in loudness for the same reason—diminution of tension. In this case the expiratory portion of the respiratory murmur is prolonged, but this is because it is prolonged at its point of origin, not because the sound is better conducted.

In collapse of the lung, whether due to pneumothorax, pleuritic effusion or pus, the growth of a tumour or by obstruction of a bronchus, the auscultatory signs are diminished in intensity, because of the relaxation of the structures. If, however, adhesions keep the organ tense, the signs are not diminished in intensity, and may even be increased.

In pneumonia and phthisis the auscultatory signs are seldom diminished in intensity, because there is rarely diminution in the tension of the bronchi, bronchioles, and alveoli. The tension, indeed, is increased, and is associated with increased density and

homogeneousness; hence the signs under consideration are increased in intensity.

In some cases of pneumonia, however, both the breath-sounds and the vocal resonance and fremitus are feebler than in health. This is because relaxation has occurred either in the parenchyma or in the bronchi and bronchioles, or in both.

In phthisis, diminution of the auscultatory signs is very unlikely to occur, because almost invariably adhesions have formed, and keep the tissues tense.

Increase in the tension of the structures forming the respiratory organs will not alone cause an increase in the distinctness of articulation, or at least not appreciably. This is shown by the fact that, no matter how much the vocal resonance and respiratory murmur may vary according to age or idiosyncrasy, these signs do not become altered in quality: puerile breathing is never bronchial breathing, and the normal vocal resonance, no matter how intense, is not bronchophony, pectoriloquy, or ægophony.

Quality of the Auscultatory Signs.

The quality of vocal resonance and the breath-sounds depends chiefly upon the amount of resonance or reverberation which those sounds have undergone before their final transmission to the ear. The more resonance that occurs, the less articulate will the voice be, and the less harsh the breath-sounds.

Hence bronchophony, however weak, is always more articulate than the normal thoracic voice; and pectoriloquy (whispered), though actually weaker than either, is much more distinct: this is because there has been less resonance or reverberation.

Ægophony is peculiar in this respect, that it is due to a preponderance of the inharmonic partial tones. It appears almost certain that this is brought about by the surface of the visceral pleura forming a stretched membrane or elastic surface in contact with a fluid medium.

A theory, such as that at present accepted, which attempts to explain the occurrence of bronchophony purely by the increased sound-conducting power of the consolidated lung, cannot be complete. Such a theory would only explain an increased intensity of the thoracic voice. Bronchophony is more than this:

it is an increase in the intensity of the thoracic voice, and also an increase in its clearness. Therefore this theory is at least incomplete.

It appears to the writer that increased clearness of the thoracic voice is due to the fact that those vibrations which occur in the air in the bronchial tubes and bronchioles are not permitted to reach the ear because of the greatly increased density of the organ surrounding them. Now, as these vibrations have undergone much reflection, the sound has become confused; but as they do not reach the ear when the lung is consolidated, the thoracic voice does not appear so confused and indefinite as it does in health.

On the other hand, the vibrations occurring in the solid tissues are increased in intensity; and as these vibrations have only to a slight degree undergone reflection (in the trachea and possibly larger bronchi), the sound occurring in them is not confused to such a great extent.

Addendum—(See page 220).

The fact that the transverse area of a bronchus is less than the sum of the transverse areas of the bronchi derived from it, is not to be found in anatomical works, so far as the writer is aware. The following is the method which was employed by him to find out this fact:—

The main bronchus and larger bronchi immediately derived from it, were dissected out from a sheep's lung and cut transversely across. The diameter of all the tubes singly was then noted, and the result worked out.

Thus if the diameter of the main bronchus be represented by a , and the diameters of the lesser bronchi be represented by $b, c, d \dots$, then the transverse area of the main bronchus

will be $\Pi\left(\frac{a}{2}\right)^2$, and the area of each of the lesser bronchi will be

$\Pi\left(\frac{b}{2}\right)^2, \Pi\left(\frac{c}{2}\right)^2, \Pi\left(\frac{d}{2}\right)^2 \dots$

Adding the areas of the less bronchi together:—

$$\text{Sum} = \Pi\left(\frac{b}{2}\right)^2 + \Pi\left(\frac{c}{2}\right)^2 + \Pi\left(\frac{d}{2}\right)^2 + \dots$$

By this means the writer found, in the case of the sheep's bronchi examined by him, that the transverse area of the main bronchus was 63·6174 sq. mm. The united calibre of the bronchi derived from the main bronchus, before they in their turn became divided up, was 75·3994 sq. mm., putting it at the very lowest. Thus the respiratory system in this respect is similar to the circulatory (M'Kendrick's *Text-Book of Physiology*, 1889, vol. ii. p. 285).

NOTE ON THE REDUCING-POWER OF THE TISSUES.

By DAVID FRASER HARRIS, M.B.

It is a fundamental conception in modern physiology that the tissues have an avidity for oxygen,—that internal or *tissue-respiration* is *the* process whereby oxygen is abstracted from the blood.

This was lately demonstrated to myself accidentally when injecting an animal for histological purposes with the Berlin-blue and gelatine mixture.

The instant the animal's heart ceased beating, it was bled from the apex of the right ventricle, and simultaneously the Berlin-blue injection through the aorta proceeded with. After the body had cooled and the organs were cut open, I was disappointed with the appearance of several of them, liver and kidneys especially,—thinking them uninjected, so pale did they appear. Parts seemed not coloured at all, others of the palest green; while in some of the large divisions of the portal vein in the liver, the gelatine mass seemed absolutely colourless. Every part of the lung was of the deepest blue.

Glancing at the little bits of liver and kidney ten minutes afterwards, I noticed they were distinctly deeper coloured; three minutes afterwards the deepening was undoubted; next morning (they had lain overnight in 10 per cent. formol), one would have said that parts were now well injected which the day before were colourless and apparently filled with gelatine only.

This was an undoubted case of de-oxidation by the living tissues, for the injection had been made so rapidly that both kidney and liver were practically 'alive,' and their avidity for oxygen uncompromised. Berlin-blue or Prussian-blue (a 2 per cent. solution) is ferric ferrocyanide—a *blue* salt; on de-oxidation it was reduced to a *ferrous* salt of light green colour; further de-oxidised (as in the liver) it was *bleached* to a colourless salt, or the chromogen of Prussian-blue.

On oxidation by exposure to air a comparatively slow recovery of colour ensued.

In these results there is nothing new,—they are only an unlooked-for variation of Ehrlich's experiments with methylene-blue, which also is bleached by de-oxidation.

In the lungs no de-oxidation occurred, because whatever small amount of oxygen the pulmonary tissue needed could be got from the air in the air-vesicles more readily than from its chemical combination in a salt of iron.

HÆMATOPORPHYMINURIA AND ITS RELATIONS TO
THE SOURCE OF UROBILIN. By DAVID FRASER
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I WOULD first of all like to allude to a case of abnormally pigmented urine, which I had the privilege of examining through the kindness of Professor M'Call Anderson, University of Glasgow.¹

It was one of those very rare cases of 'burgundy-red' urine similar to two examined by M'Munn, and published by Ranking and Pardington (*Lancet*, 1890, vol. ii. p. 607).

The pigment here and in Professor M'Call Anderson's case—one of dermatitis hypetiformis bullosa—was not uro-hæmatoporphyrin, but a closely allied body, believed by M'Munn to be less de-oxidised than uro-hæmatoporphyrin, or than urobilin. M'Munn has not named it; and as it is awkward to have to allude to it always by a periphrase, I suggest that it be known as *Meio-de-oxy-hæmatoporphyrin*.

The urine in the case I examined was claret-coloured, did not give the guaiac reaction, did not contain biliary pigment, nor any proteid. With the spectroscope it showed very distinctly a four-banded absorption spectrum, closely resembling that of uro-hæmatoporphyrin, with one band in the red, two between D and E lines, and one band near the F line.

Such a reducing substance as ammonium sulphide had no effect whatever on the pigment, which, had it been met-hæmoglobin—a vastly commoner four-banded pigment—would have been reduced through oxy-hæmoglobin to hæmoglobin; but treatment with concentrated sulphuric acid instantly gave rise to a pigment with the characteristic double-banded absorption spectrum of acid-hæmatoporphyrin.

On careful spectroscopic examination there was no possibility of confusing this rare pigment with met-hæmoglobin, as in the

¹ The case is published in the *Scottish Medical and Surgical Journal*, February 1897. (Jack and Borland on a case of Hæmatoporphyrinuria).

former the band to the right of D is much fainter than the homologous band of the latter.

The patient was a young Highland fisherman (æ. 25), who had suffered for several years from an annual eruption (from April to October) of a vesicular type. Ten to twelve hours before the formation of the blisters there was intolerable itching, but he had no headache nor malaise. The blood showed no diminution in the number of corpuscles; the hæmoglobin, however (with Gower's instrument), appeared to be only 60 per cent. of normal; spectroscopically, it yielded no bands beyond the two of HbO_2 .

Beyond all doubt, hæmoglobin, through its pigmentary element the hæmatin, is the parent of the pigments of the bile, and the chief pigment of the urine (urobilin)—(indican and other allied pigments being derived from an aromatic molecule, phenol and its substitution-compounds, originally resident in proteid material metabolised in pancreatic digestion). Hæmatin—an iron-containing substance—is the source, on the one hand, of bilirubin or biliverdin, iron-free pigments; and on the other, of urobilin, also an iron-free pigment; but in what manner, as to parentage, are these pigments of the bile and urine related to each other? Are they members of the same generation, or is the bilirubin the progenitor of urobilin? The former supposition seems to be more in accordance with facts, though certain of the text-books will be found to dismiss the subject by upholding an old view, which, stated more in detail, is, that the bile-pigment in the intestine is acted upon by nascent hydrogen there, and that a reduction-product (considered by Maly identical with hydro-bilirubin, formed by the action of sodium amalgam on bilirubin) is thereby produced, that this is absorbed into the portal system, passes through the liver without (apparently) undergoing any change or being excreted into the bile, is sent on to the right side of the heart, and so, *via* the lungs, into the arterial stream from which the kidney removes it as urobilin.

Before giving reasons for adopting the view that the bile-pigment and the urine-pigment are derivatives of hæmatin of *equal remoteness* from it, and are not derived the one from the other, we might point out the unlikely nature of the hypothetical

process just explained. In the first place, it is tantamount to saying that hydro-bilirubin exists in arterial blood—of this there is no evidence—*cf.* p. 311, Halliburton, *Physiological Chemistry*; secondly, later work has shown that urobilin is much more nearly related to choletelin—the fully oxidised biliary pigment—than to hydro-bilirubin, the least oxidised; thirdly, it seems most unlikely that so constantly-present a body as urobilin should depend upon the presence in the intestine of ‘nascent hydrogen,’ which must vary in amount from hour to hour, according to the amount of putrefactive decomposition; fourthly, it is purely conjectural that, whereas bilirubin gets thrown out into the biliary secretion, its next ally, hydro-bilirubin (granting that its absorption by the portal radicles is a fact, or is possible) passes on through the liver, escaping separation from the blood, and so reaches the heart and arterial circulation.

A greater objection than any of these is, that both in the lower animals and in the human being, in the case of a biliary fistula, where no bilirubin gets into the intestine at all, and where the fæces are colourless, the urine contains urobilin in undiminished amount; and in Copeman and Winston’s case, at times in increased amount.¹

In the face of these considerations, we cannot regard bilirubin as the parent of urobilin; rather, both pigments are derivatives of hæmatin, of equal degree of remoteness therefrom.

If a function is to be found for ‘reduction’ in the intestine, there is the obvious one of altering bilirubin or biliverdin to stercobilin, as Copeman and Winston suggest, p. 231; but if, as Garrod and Hopkins maintain,² the pigments of bile and of fæces are identical, all we can say is, that we have one more member of the generation—stercobilin—produced in the liver from the common ancestor, hæmatin. M’Munn, indeed, had previously contended that stercobilin was more closely allied to ‘pathological urobilin’ than it was to bile-pigment.

Although the bile-pigment cannot be regarded as the source of the urinary-pigment, it is highly probable that the liver is the seat of the formation from hæmatin of the antecedent of urobilin, which is not excreted externally by the hepatic cells

¹ *Journal of Physiology*, vol. x. p. 228.

² *Journal of Physiology*, vol. xx. Nos. 2 and 3.

into the bile-canaliculi, but internally into the hepatic blood. This is an '*internal secretion*' for the liver, if that of glycogen be denied it. That increased metabolism of hæmoglobin in the liver is at once followed by the secretion of an increased amount of urobilin in the urine, while the liver has additional iron deposited in it, is well known.

If hæmoglobin be by any means dissolved out of the corpuscles *in the circulating blood* we have hæmoglobin or met-hæmoglobin in the urine,—as, *e.g.*, after the injection of foreign blood, injections of water into the blood, in extensive burns, in Raynaud's disease, after the injection of many toxic substances, bile salt, etc.; in other words, the blood-pigment in these cases is not decomposed into hæmatin, nor is hæmatin de-oxidised in hæmoglobinaemia: the pigment circulates as oxy-hæmoglobin dissolved in the plasma, and is excreted *as such*¹ by the kidneys,—another incidental proof that in the blood itself de-oxidations do not go on.

In the liver it is very different: its pre-eminence as *the* urobilin-forming body is well brought out in the case of pernicious anæmia, in which, as Mott, Delépine and Hunter have shown, there is an abnormally active destruction of red discs, with a correspondingly *augmented* secretion of urobilin, or its less fully oxidised ally 'Pathological Urobilin' (which has, besides the band at F, two between C and E lines). The amount of urobilin present in normal urine is not sufficient to yield the band at F, which appears as soon as the urine is evaporated down to about $\frac{1}{2}$ its bulk; if, therefore, one can see the band at F in a fresh specimen of urine unsophisticated chemically (and provided the urine does not give Gmelin's test for bile-pigment), one is dealing with a case of excessive excretion of the normal urinary pigment; but if, in *addition* to this band, the two between C and E are present, the pigment is 'Pathological Urobilin,' the more completely de-oxidised form of urobilin. Thus, if the hepatic metabolism be still normal in quality, but only unusually excessive in degree, we have an excessive amount of normal urobilin in the urine; if, however, the hæmatin-reduction goes beyond the limit of the

¹ The final reduction does not endure sufficiently long to form reduced hæmoglobin.

formation of urobilin, we have the more completely de-oxidised pigment (Pathological Urobilin) appearing in the urine.

So much for the *hepatic*, as opposed to the *biliary*, origin of urobilin. On this view, urobilin or its chromogen (whichever, in the absence of positive proof, be regarded as the internal secretion of the liver) would of necessity require to be found in the blood. I may say at once that I believe urinary-pigment is present in blood-plasma, and therefore in blood-serum, although bile-pigment is not.

M'Munn long ago discovered¹ that sheep's serum yielded a spectrum with a band at F, and even then (1880) he remarked it must be due to "choletelin, or a substance like it." But even at that time Maly, Neubauer, and Vogel believed it was due to urobilin; and as our knowledge of all these substances has been considerably increased in these seventeen years, we are by no means compelled to say that a pigment, choletelin, which is only known in the laboratory, is present in the blood, when we have just as much evidence for believing that another—urobilin—constantly in the body, is the pigment in the blood. The objection that we see no band at F in normal blood has no weight whatever, because (1) urobilin will be in all likelihood present in blood in much less percentage than in urine, in which the urobilin present is spectroscopically invisible; and (2) because it is quite conceivable that it might exist in the blood (partly) as the colourless chromogen of the pigment.

By a chromogen, we understand the precursor of a pigment, a colourless body, which on oxidation will yield the pigment, and which can be again obtained by de-oxidising the pigment.

But there is evidence that the katabolism of hæmatin can proceed in other organs or tissues than the liver. It is a commonplace of clinical knowledge that in febrile diseases the urine is 'highly coloured.' In recent years, largely due to M'Munn's work, it is known that this increased depth of pigmentation is the result of either an excess of normal urobilin or the presence of 'Pathological' (originally called 'Febrile') Urobilin in the urine.

Now, in fevers we have increased tissue-change, a more than

¹ "Researches into the Colouring Matters of Human Urine," *Pro. Roy. Soc.*, 1881, p. 231.

usually active blood-katabolism going on, which is evidenced not only by the elevated temperature, but by the increased amount of urinary pigment appearing. The muscles undoubtedly are the seat, in many fevers, of this excessive katabolism, part of the expression of which is the increased destruction of hæmatin owing to the exaltation of the normal tissue-avidity for oxygen, with the subsequent appearance either of an excessive amount of a hæmatin-derived pigment (urobilin), or, by reason of the very vigour of the metabolism, an unusually de-oxidised form of it,—Pathological Urobilin.

M'Munn, in his chart accompanying the paper "On the origin of Uro-hæmatoporphyrin and of Normal and Pathological Urobilin in the organism,"¹ shows that urobilin must be regarded as more fully oxidised than Pathological Urobilin, and than stercobilin if its hepatic origin and identity with Pathological Urobilin be believed in.

We have further evidence that other tissues than the hepatic katabolise hæmatin,—extravasations of blood under the skin or fasciæ usually give rise to an increase of urobilin, and we know that in these clots hæmatoidin, an iron-free though crystalline pigment, is produced. The chief *other* tissues or 'systems' which could by any possibility be sufficiently extensive seats of this metabolism are (1) the muscular, (2) the cutaneous, and (3) the connective-tissue, articular and skeletal.

The blood which reaches the kidney is entirely arterial, being a portion of the main aortic stream which has passed through the lungs, having been collected from very different sources and mixed in the right auricle. Now, from a *chemical* point of view, the blood of the right side of the heart may be viewed as having proceeded from precisely these two main sources—(I.) the liver, (II.) from the systems (1), (2), and (3), as above indicated (to which, no doubt, the venous blood of the head has to be added).

The bloods from both (I.) and (II.), which may be for physiologico-chemical purposes thought of as distinct, pass through the lungs, where oxidation is the pre-eminent process, and thereafter are distributed to all parts of the body where *de*-oxidations are equally characteristic.

¹ *Journal of Physiology*, vol. x. p. 71.

Now, M'Munn made urobilin artificially by (1) oxidising hæmatin by the action of peroxide of hydrogen, and (2) subsequently briefly de-oxidising it with sodium amalgam (*cf.* his last-mentioned paper): what have we in the body but these very two processes, for whether the hæmatin be freed of its iron in the liver, or be so in the muscles, skin, and connective-tissues, the pigment-antecedent so formed passes in both cases to the lungs, where it must be thoroughly oxidised, and then, during excretion by the renal epithelium, would suffer a "subsequent brief reduction." It may be supposed that the chromogen of urobilin is already formed when the substance reaches the lungs, and that it is there oxidised (more or less perfectly) to the pigment, which, in the kidneys, undergoes a partial de-oxidation to the chromogen. (It is a familiar fact that urine deepens in colour as it stands after being passed: this may be due to a partial re-oxidation of the chromogen.)

We are now in a position to inquire under what conditions uro-hæmatoporphyrin supplants urobilin, wholly or partially, as the urinary pigment.

Hæmatoporphyrin, as we know it in the laboratory, is either an acid or alkaline solution of iron-free hæmatin. Acid-hæmatoporphyrin can be rapidly made by adding a very little defibrinated blood to an excess of strong sulphuric acid. This gives the two-banded spectrum—one thin band to the left of D, and one much broader, darker band to the right of D, there being intermediate a narrow zone of obscured yellow light. There is no band at F.

This pigment can be precipitated by the addition of water, and then dissolved in ammonia, giving alkali-hæmatoporphyrin with a four-banded spectrum.

Uro-hæmatoporphyrin, as found in urine, has a four-banded spectrum closely resembling the last mentioned, but with this important difference, that the left of the two bands between D and E is much fainter in the former pigment; but M'Munn has managed to manufacture in the laboratory a pigment from hæmatin which yields by successive *reductions* hæmatoporphyrin (acid or alkali) and uro-hæmatoporphyrin. When his chief paper on hæmatoporphyrin was published he had not met with his cases of meio-de-oxy-hæmatoporphyrin, but he has since assigned

a place to it by regarding it as less de-oxidised than uro-hæmatoporphyrin: the series of bodies in descending scale of possession of oxygen would therefore be—hæmatin, hæmatoporphyrin, meio-de-oxy-hæmatoporphyrin, uro-hæmatoporphyrin, Pathological Urobilin.

[M'Munn actually made uro-hæmatoporphyrin by reducing hæmatin with zinc and sulphuric acid, and further reduction yielded a pigment identical with Pathological Urobilin; but he failed to produce it from bilirubin.]

If one makes a survey of the diseases in which uro-hæmatoporphyrin has been recognised, it is noticed that they all present lesions of one or other of the systems (1), (2), or (3), as given above.

Thus, those involving the muscular system or connective tissue, or most probably both at once, are acute rheumatism, pericarditis, meningitis, peritonitis, and cirrhosis of liver.

Three are the acutely febrile, croupous pneumonia, typhoid, and measles,—the last two with cutaneous involvement; also Addison's disease and Hodgkin's disease,—both disorders of pigmentary metabolism, and involving a cutaneous factor. [Hæmatoporphyrinuria has also been described by Oswald¹ in sulphonal over-dosing in the insane, and Stokvis produced it by feeding rabbits with sulphonal.²] Lastly, of three cases of meio-de-oxy-hæmatoporphyrin, two of them are obscure, being in neurotic women, but one was a case of profound cutaneous lesion (Professor M'Call Anderson's).

Briefly, then, we may say, that in health pigmentary metabolism in the three great systems already alluded to forms from hæmatin the urobilin-chromogen, that this on traversing the lungs is oxidised to urobilin, which on traversing the kidneys is partly de-oxidised to the chromogen, partly excreted as urobilin. It is probable that even in health a certain quantity of "Pathological Urobilin" is formed by these three systems, but is partly de-oxidised to its chromogen at renal elimination. M'Munn has, however, seen 'Pathological Urobilin' in stale *normal* urine. That on being passed the bands of Pathological Urobilin are not seen, is perfectly explicable on the supposition that it is, like urobilin, present in too small quantity to give a spectrum,

¹ *Glasgow Medical Journal*, January 1895.

² *Centralblatt für physiol.*, 25th July 1896.

and that much of it exists as the chromogen. It is perhaps time to re-name the pigment by a term connoting nothing pathological,—*para-urobilin* might suffice.

If, however, metabolism in these systems is excessive, as in certain febrile disorders, in which the chemical changes are carried to an abnormal extent, we have either an exaggeration of the normal formation of the urobilin-chromogen, giving rise to *an excessive quantity* of normal urobilin to be eliminated by the kidneys, or, by the initial reduction of hæmatin being carried beyond the normal limit, the chromogen of a more de-oxidised pigment than urobilin produced, viz., Pathological Urobilin, which supplants the ordinary pigment in the urine. Lastly, if the metabolic changes in these three great systems become 'depraved,' altered, or abnormal in some way as yet not fully understood, we have the initial hæmatin-reduction process arrested at some intermediate stage, so that there are formed reduction-products of hæmatin less de-oxidised than urobilin or pathological urobilin, and these appear in the urine in order of nearness to hæmatin, meio-de-oxy-hæmatoporphyrin in very rare cases, and less rarely uro-hæmatoporphyrin.

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A CASE OF POLYPUS OF THE PYLORUS, WITH INTUSSUSCEPTION. By PETER THOMPSON, M.B., Ch.B.,
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THE specimen now described and illustrated by the accompanying figure¹ was found in a female subject, aged 75 years, in the dissecting-room of The Owens College, Manchester. It is of special, and indeed almost unique interest, because of its rarity. So far as I have been able to ascertain, no precisely similar case has hitherto been recorded, though one described by Breschet² in 1816 resembles it in many particulars. In Breschet's case there was a polypus growing from the gastric mucous membrane, which passed through the pyloric orifice into the duodenum. There was not, however, the concurrent intussusception which forms so striking a feature in my specimen.

Description of the Specimen.

On opening the abdominal cavity a large ovoid mass was discovered, occupying the interior of the second part of the duodenum. It was freely movable inside the gut, and was apparently quite separate from the stomach. The latter was somewhat distended, though not markedly so, and its walls were much thinned. There was an obvious thickening in the region of the pylorus, and both it and the first part of the duodenum were distinctly invaginated. After the parts had been opened up, it was seen that the mass referred to was the enlarged bulbous end of a polypoid growth, projecting from the inferior margin of the pyloric ring. Its basal attachment extended for a distance of about two inches along the duodenum, and formed a somewhat conical expansion, which dwindled down to a slender, rounded, and twisted pedicle. To its lower end was attached the globular polypus, which

¹ From a photograph, for which I am indebted to Dr N. H. Alcock.

² G. Breschet, *Fac. de Méd. de Paris*, 1816-1817, p. 376.

hung quite freely in the lumen of the intestine. It was of firm consistence and about the size of a walnut, with a diameter of three quarters to one inch. The fundus was deeply retracted, forming a pit-like depression, the margins of which were notched. The surface generally was quite smooth, and showed no ulceration. An examination of the intussusception proved that the pylorus and the first part of the duodenum had passed into the second part of the duodenum, and formed a prominent mass, to which the pedicle of the tumour was

S, stomach, opened at pyloric end, showing basal attachment of tumour ; D, duodenum, laid open, showing polypoid growth *in situ* ; P, pancreas.

attached. The advancing point of the intussusception was the circular fold of the pylorus, and its muscular fibres were clearly seen in section. A few small vessels—branches of the superior pancreatico-duodenal artery—were included between the opposed peritoneal surfaces, but there were few or no adhesions. The intussusception was apparently a recent complication, since reduction readily occurred after the parts had been dissected. The longitudinal folds of the mucous membrane in the pyloric part of the stomach were much accentuated, and the pyloric orifice correspondingly encroached upon. The

pyloric ring was dissected out; instead of exhibiting its usual arrangement, it had assumed a very oblique position, the lower end having been dragged downwards by the growing tumour.

Microscopic Examination.

The expanded base of the pedicle consisted of both gastric and duodenal mucous membrane, much hypertrophied, which, though more or less fused, occupied definite positions in the structure, the former being on its upper and the latter on its lower surface. The peripheral parts of the tumour itself showed sections of gland tubes, the epithelium of which had undergone considerable degenerative and post-mortem changes. Deeper, the gland structures were much increased in number, whilst the central parts consisted of an irregular arrangement of muscular and connective tissue. There was extensive cell-infiltration throughout the section, and at one part both villi and ducts of pyloric glands were observed. Although there was evidence of proliferation of gland elements, the main portion of the tumour was composed of fibro-cellular tissue. The polypus may therefore be regarded as having originated at the pylorus, and as being fibro-adenomatous in nature.

Remarks.

Although the tumour was evidently of old formation, it is interesting to note that it apparently gave rise to no symptoms, and this is the more remarkable since it seemed to occupy the greater part of the lumen of the gut. Indeed, at one point it led to protrusion of the wall of the duodenum, and to the formation of a distinct pouch, apparently the result of mechanical distension. This was situated just below the head of the pancreas, and a short distance from the biliary papilla. It appears to be an example of the simple or non-inflammatory form of pouch of the duodenum described by Drs Perry and Shaw.¹ In this case a definite cause existed which would explain the occurrence of spasmodic contractions necessary

¹ *Guy's Hospital Reports*, vol. v., 1893. "On Diseases of the Duodenum." By E. C. Perry, M.D., and L. E. Shaw, M.D.

for its production. Further, the basal attachment encroached upon the pyloric opening, and the gastric portion of the pedicle could be traced through it continuous with the gastric mucosa. That there was not complete obstruction was proved by the fairly free passage of fluid from the stomach through the pylorus and past the growth.

The subject was somewhat emaciated, but the organs generally were healthy. The cause of death was certified as "senile decay." I was able to ascertain that for some months before death there had been no gastric disturbance, and no symptoms to lead one to suspect the presence of the growth. Dr Moore¹ has also recorded a case of polypus of the stomach in which no symptoms of the disease were present during life. In his report he says,—“The polypus was from a man aged 68 years, who died of bronchitis, and it had given rise to no symptoms during life. Some specimens of polypi of the small intestine have been shown to the Society this year, but polypi of the stomach are less frequent. There are three specimens of the kind in the Museum of St Bartholomew's, but the infrequency of the growth is shown by the fact that the present specimen is only the second which has been observed in the last three thousand post-mortem examinations.”

Other cases are recorded, however, in which the signs of intestinal obstruction were present. In the one described by Breschet² the polypus was attached to the small curvature of the stomach, three inches from the cardiac orifice. It passed into the duodenum, and was slightly constricted by the pylorus. The symptoms were those of chronic obstruction.

In 1827 Webster³ described a case of bony tumour obstructing the pylorus, terminating fatally from intestinal obstruction.

Apart from the clinical features, however, this case is interesting in relation to the etiology of intussusception. An illustration of invagination due to a polypus so high up in the alimentary tract does not seem to have been previously recorded. Dr Hale White⁴ has pointed out the rarity of intussusception in

¹ *Transactions of the Pathological Society*, vol. 34, 1883, p. 106.

² *Loc. cit.*

³ *The London Medical and Physical Journal*, 1827, p. 433.

⁴ *Transactions of the Pathological Society*, vol. 41, 1890, p. 121.

the adult, and its greater rarity in the upper part of the alimentary canal, and also the fact that it is rarely due to a polypus.

Further, in the *Guy's Hospital Reports* it is noteworthy that in 17,652 autopsies only four cases of innocent duodenal tumour were met with, and in none of them was there intussusception.

It is, however, not unusual to meet with intussusception in the rectum due to polypi, and in the *Pathological Transactions of London* there are numerous records of this condition, even as high as the jejunum. There seems, therefore, no reason why polypoid growths should not prove determining factors in the production of intussusception still higher up than the jejunum, and the case now recorded affords an excellent example of this occurrence.

The probable sequence of events during the growth of the tumour was as follows:—Springing from the mucous membrane of the pylorus and adjacent part of the duodenum, the new formation would project downwards, and tend to drag on the gastric mucosa. This would excite increased peristaltic action of the stomach and duodenum, which would be more or less continually exerted in striving to force the tumour onwards. Food passing over it would act in a similar manner. The mucous membrane in the vicinity of the attachment of the pedicle would accordingly hypertrophy, and be dragged onwards into the duodenum. As regards the production of the intussusception, it is probable that it was formed during violent or irregular peristalsis, and in this specimen the invagination commenced at that portion of the gut from which the polypus originated. At the same time it is possible, bearing in mind the relative diameters of the two parts, that the intussusception may have supervened as a result of simple traction of the pedicle.

OBSERVATIONS ON THE HISTOLOGY OF MEDULLATED NERVE FIBRES IN MAN AND RABBITS, DERIVED FROM A STUDY OF THEIR PATHOLOGICAL ANATOMY. By ROBERT A. FLEMING, M.D., F.R.C.P.E. (PLATE XV.)

IN this paper I purpose discussing—

1st. The neurokeratin network of medullated nerve fibres ;

2nd. The probable function of this neurokeratin network in the production of segmentation of myelin in Descending Degeneration, and its possible function in Regeneration ; and

3rd. The existence of an epithelial membrane interposed between the myelin sheath and the neurilemma.

Firstly. I was induced to examine very closely the neurokeratin network of medullated nerve fibres in peripheral nerves, because the results of using one method for both normal and degenerated nerves appeared to throw some light upon this much discussed subject. In the first place, I succeeded without using silver salts in staining by hæmatoxylin the funnels of Golgi and Rezzonico in human nerves (see Figures 1 and 2), and they seem to me to offer a very satisfactory explanation of the slits of Lantermann. In many of my specimens so stained, the spiral thread can be distinctly made out constituting the funnel.

But before entering upon the more original observations contained in this paper, it seems very desirable to give a brief resumé of our knowledge of this neurokeratin network. The medullary sheath consists of a substance called myelin, supported by a network of some sort. Myelin is a mixture of lecithin, neurin, cholesterin, and other substances in smaller amount which readily absorbs water, and swells up when exposed to the action of water, alcohol and many other reagents giving the nerve fibre an irregular outline, the myelin within forming irregular oval segments. When broken up into droplets, either within the sheath of Schwann or when expressed from the sheath, each droplet has a typical optical property, namely, a

double contour, which in reality depends on the manner in which myelin refracts light. The myelin is supported by a framework; and the nature of part, at least, of this has been most conclusively proved by Rezzonico and Golgi. They consider it to be a chain of funnels, practically enclosing the axis cylinder in a sort of canal. This canal is an interrupted one in the peripheral nerves, but is more continuous in the medullated fibres of the cord and brain. The existence of these funnels can be demonstrated by other methods than the silver one; and I believe the distortion of the spiral threads constituting the funnels, accounts for much of the network-like appearance described by many writers.

Ewald and Kühne,¹ in 1876, prove by means of gastric and tryptic digestive fluids, and by dissolving out myelin by means of ether and alcohol, the existence of a horn-like substance. Ewald and Kühne believe that there are two keratin sheaths, one closely applied to the axis cylinder, and the other between the myelin and the sheath of Schwann, probably due to a reflection of one and the same sheath at the node of Ranvier, and that there exists a cement substance uniting the two sheaths together.

Tizzoni² believes that there is but one network closely investing the axis cylinders, which he thinks is in connection with the slits of Lantermann.

Rumpf, Th.,³ agrees with Ewald and Kühne. He thinks there are two sheaths, with myelin between, narrowed, but not interrupted at the nodes of Ranvier; that there is an albuminoid substance in these sheaths which can be digested with trypsin, leaving behind a neurokeratin substance; and a cement substance, which latter may be responsible for the slits of Lantermann.

Koch⁴ denies an outer sheath. He finds evidence of a strong cement substance between the medullary segments.

Chittenden, Gedoelst, Schiefferdecker, Paludino, Joseph, and Leydig all hold that there is a network supporting the myelin; whereas, on the other hand, an array of writers—Pertik, Engelmann, Gerlach, Hesse, Waldstein and Weber, Lawdowsky, Kölliker, Boveri, von Büngner, and Stroebe—consider that either the network is an artificial

¹ Ewald, A., and Kühne. "Die Verdauung als histologische Methode. Ueber einen neuen Bestandtheil des Nervensystems." *Verhandl. des Naturhist. med. Vereins zu Heidelberg*, Bd. 1, 1876.

² Tizzoni. "Sulla patologia del tessuto nervoso-osservazione ed esperimenti sulla istologia normale e patologica della fibra nervosa." *Archiv. per le Sc. Med.*, vol. iii., fasc. 1, 1878.

³ Rumpf. "Zur Hist. der Nervenfasern und des Axencylinders." Sonder abdr. aus den *Untersuchungen des Physiol. Instit. der Universität*, Heidelberg, Bd. 2, H. 2, 1878.

⁴ Koch. "Zur Kenntniss der Markhaltigen Nervenfasern." *Tagebl. der 51 Vers. deutschen Naturf. und Aerzte in Kassel*, 1878, S. 262.

product of alcohol and ether, and does not exist in a normal nerve fibre, or else that it may be a post-mortem change.

On the other hand, Ranvier, Gad, and Heymans believe that there is an albuminous substance in the medullary sheath, and that the network merely means an artificial separation and deposit of this substance, due to the chemical agent employed.

Von Stilling, Roudanowski, Lantermann, and M'Carthy believe that there is a system of hollow canals in the white substance of Schwann, and that the canals are connected with the axis cylinder. They think that the network-like appearance may be referable to this.

In my own experience of Müller specimens, now extending over several years, I believe that no better agent exists for the preservation of nerve fibres than certain solutions of chromic salts; and that if the specimens are properly hardened in one of these solutions, and then in carefully graduated methylated spirit, much of the network so frequently described is conspicuous by its absence.

The method I preferred for fixing and hardening peripheral nerves was Müller's fluid, prepared in the following way:—

| | | | | | |
|-----------------------|---|---|---|---|------------|
| Potassium Bichromate, | . | . | . | . | 2 parts. |
| Sodium Sulphate, | . | . | . | . | 1 part. |
| Distilled Water, | . | . | . | . | 100 parts. |

This solution was changed daily for a week, then weekly for six weeks, and at the end of the third week I generally increased the amount of bichromate to three parts in place of two. After six weeks, the longer the nerves could be left in Müller's fluid the better—up to a period of *at least* six months. The specimens were then changed, generally without washing in water, into 60 per cent. methylated spirit, and the spirit renewed as often as it became coloured. A week later they were placed in 80 per cent., and so on through 90 per cent. and 95 per cent., till they were in ordinary full strength methylated spirit. I found it of the utmost importance to keep the specimens in the dark; and even when saturating in naphtha upon the stove for paraffin imbedding, they were shielded from the light. Light appeared greatly to increase the tendency to precipitate in the medullary sheath, both upon the neurokeratin network and irregularly throughout the myelin.

If, however, the specimens are not properly hardened when transferred to methylated spirit, whether it be to 50 per cent. or to full strength, the network in the myelin becomes very evident; and one other fact is of interest, namely, that even in fairly well hardened specimens the network becomes very much

better marked where degenerative changes are present. This appears to point to the possibility of an artificial addition at least to the network.

An early stage of degeneration of the myelin frequently demonstrates its existence by a slightly granular appearance of the medullary sheath, and this, too, may be simulated by a deficient fixing process with chromic salts. The network and the granular precipitate just referred to stain deeply with aniline dyes. In some of my experimental specimens, which were finished too late for satisfactory fixation and hardening in Müller's fluid, the granular appearance in the myelin shows very distinctly, the granules grouped round the axis cylinder being generally best marked between the nodes of Ranvier, and looking as if the axis cylinder had burst, and the granular exuded material had taken on the aniline stain as deeply as the axis cylinder itself. In a hurriedly fixed Müller specimen of a perfectly normal nerve, this accumulation of deeply stained granules round the axis cylinder is very marked, but it is not entirely absent in a nerve well fixed and hardened in Muller's fluid and alcohol. This appearance has been referred to by Stroebe as the cyanophile granules of the medullary sheath, which tend to take on aniline blue by his staining method, and require considerable bleaching in potash alcohol before they can be decolorised. It seems probable that as the funnels of Golgi are not placed very close together in the peripheral nerve fibres, the aggregation of the cyanophile granules may be at the angle of approximation of funnel and axis cylinder.

The conclusion, therefore, which I have arrived at is, that the neurokeratin network is in many cases due to the spiral threads of Golgi's funnels, often much twisted, and to a deposit on them of albuminoid or other particles, which stain very deeply with many dyes. It only seems natural to suppose that these appearances should be best marked between the narrower part of the funnel and the axis cylinder; while the cyanophile granules may be derived from the axis cylinder, or as above stated.

If Figures 1 and 2 be examined, the appearances are well seen. They were taken from the nerves of a case of Diabetic Neuritis, fixed and hardened as described above, taken through

naphtha and paraffin, and stained with hæmatoxylin. The funnels of Golgi show by this method very distinctly in fibres which have undergone slight degenerative change,—whether as the result of a more marked precipitate on the spiral threads than in health, or not, I cannot say. A careful inspection of the Drawings show a very well marked twisting of the threads, and what looks like an opening out of the spirals in some parts. May this distortion of the threads, produced artificially, and, so far as I can judge, more readily so produced where a degenerative process is present, not account for part of the neurokeratin network described by so many writers?

But there is another arrangement of fibres forming a network to which less attention has been directed. When a nerve fibre is examined in transverse section, the myelin may be seen divided into two layers in certain fibres, and the relative thickness of these layers depends on the part of a funnel of Golgi which chances to be in the section. But, apart from this in fibres which show no evidence of a funnel on transverse section, delicate strands may be seen running between the axis cylinder, or the sheath covering it, and the neurilemma, dividing up the myelin in a radial way, much like the spokes of a wheel, only of more sinuous outline. In sections showing a funnel, these strands run between the outer portion of the funnel and the neurilemma, but I cannot distinguish them between the axis cylinder and the inner side of the funnel. These threads are seen, but not well seen, in normal nerve fibres, carefully fixed and hardened, but are very obvious indeed in many slightly degenerated fibres. They are well seen in Figure 3, in the two normal fibres represented in the lower right-hand corner.

It is of special interest to find these strands so faint and indistinct in healthy nerve fibres of man, rabbits, and dogs, yet becoming so easily recognised in slightly degenerated fibres when the specimens are fixed and imbedded by the method I used, because it helps to explain why they have been apparently overlooked. Are these threads artificial? Why are they better marked in degeneration up to a certain degree? Are these the slits of Lantermann? These questions are hard to answer. Let me next deduce from pathological specimens the apparent

existence of these fine strands, if strands they are, in health. I would just remark before doing so, that the artificial radial striation of myelin, so readily produced by picric acid, corrosive sublimate, etc., is totally different from the appearance described here.

Secondly. These strands or threads appear to have an important influence on the mode of segmentation of myelin (when Müller's fluid and paraffin imbedding are used) in degeneration; and in regeneration of nerve fibres they appear also in certain cases to have a definite function.

Descriptions of this degeneration are familiar, and they do not vary to any very great extent; but I must refer to the main points of difference between the results of my own experiments, and the views generally accepted, so far as they concern the subject under discussion.

As generally stated, then, the process begins at the point of section of a nerve with a swelling of the axis cylinders, which become irregular in outline, showing bulgings and longitudinal groovings at different parts. This change in the course of a further twenty-four hours becomes widely spread along the nerve, but it is only well seen in portions of the nerve fibre, other parts of the same fibre being apparently normal. The medullary sheath now breaks up, at first into ellipsoids, with the axis cylinder passing through them; but after the second day the axis cylinder begins to break across, and the myelin ellipsoids become more circular, many of them embracing a portion of the axis cylinder which has in this way been broken off. These myelin balls have the typical dark contour (stained with Weigert's hæmatoxylin, or osmic acid) of myelin droplets, whether inside or outside of a nerve fibre. The myelin balls undergo still further division, slits appearing in their margin, which deepen so that portions of myelin become divided up into smaller and smaller balls. The axis cylinders probably disappear absolutely in about six weeks—at least they cease staining; and it is very unlikely that, as Korybutt-Daskiewicz states, the axis cylinders persist, and that from the fragments new ones can be originated. Eventually the whole of the myelin is absorbed, and the nerve fibre shrivels up.

Now, I cannot understand why myelin should be always and

only described as breaking up at first into a *single* row of ellipsoids or balls. A glance at Figure 4 will show what I believe to be three stages in the process of myelin segmentation: not in all fibres, perhaps not even in the greater number of fibres, but in some. In a badly fixed nerve fibre artificial shrinkage could possibly produce the changes shown in the right-hand drawing, but not if well fixed.

The three drawings constituting Figure 4 were taken from a rabbit's sciatic. In the right-hand drawing the myelin may be seen in droplets between the axis cylinder on the one side, and the primitive sheath or neurilemma on the other. These droplets tend to press on the axis cylinder and give it a sinuous outline. Is it possible that the Schmidt-Lantermann slits have something to do with this cleavage; or rather, do not the strands I have just described help in the explanation? The myelin droplets may either run together or eventually subdivide still more.

If von Büngner and Stroebe are correct in their description of segmentation of myelin always giving rise to ellipsoids, and the axis cylinder breaking up and eventually becoming enclosed in these, at which period they assume a more circular shape, then how can all the drawings in Figure 3 be explained?

Glancing at this Figure taken from a rabbit's sciatic, but which might have been taken from the peripheral part of many of my rabbit's nerves, after section or ligature, up to four weeks, an axis cylinder is noted in the distended fibres; and with it, acting apparently as a kind of central support, the outlines of a number of myelin droplets are seen. Where the axis cylinder persists at all, this arrangement is observed (drawings 1, 2, and 3); whereas, when it is not visible, the droplets appear to have no central support (drawings 4 and 5) at all. The axis cylinder may persist, though not well stained. The two series of figures may be explained, I believe, by the admission that segmentation may take place around the axis cylinder, and probably largely determined by the threads or strands running from the axis cylinder to the periphery.

Turning again to Figure 4, the middle-drawing shows how one large myelin droplet may push the axis cylinder to one side; and the left-hand drawing shows a whole congeries of myelin

droplets, which might be the condition secondary to either the ellipsoid theory or the one I have just propounded. I have observed this cleavage of the myelin into several rows of balls in many of the rabbit's nerves, and in every one of my cases of Peripheral Neuritis in man.

The reason why this cleavage of myelin into several rows as an initial stage of Descending Degeneration is not found recorded by von Büngner and Stroebe is, I believe, because neither of them appear to use the paraffin method in the way described.

Celloidin sections do not show the same congeries of myelin droplets as paraffin specimens do. In the earlier stages of Wallerian Degeneration the celloidin process practically never shows this condition; and in a badly fixed specimen, in place of seeing a representation of the right-hand drawing of Figure 4, the myelin is merely seen to be granular. Ether, in the celloidin process, has a powerful effect in producing segmentation of normal myelin into large ellipsoid-like masses, unless with extremely well fixed and hardened specimens; and there is no reason why degenerated myelin should not suffer to a very much greater extent, which in fact it does. Chloroform is equally baneful in its effect on myelin, and yet many writers use it, no doubt mainly for specimens fixed by Flemming's solution (the strong or weak formulæ), but even then it can still act harmfully. In many of my own specimens cut in paraffin, the axis cylinder, or the remains of it, may be seen pushed to one side by a big myelin ball, while comparatively rarely are the remains of the axis cylinder found in the interior of the balls of myelin; far more generally they are found taking up a position between them.

There is, therefore, evidence not merely of the spirals of Golgi and Rezzonico, but of a network of fibres or strands running between the axis cylinder and the periphery. These strands may be cement substance: they are too numerous and wavy in outline to be the slits of Lantermann, and they seem very commonly to determine the cleavage of myelin in Descending Degeneration. Of course I admit the element of novelty in this theory of cleavage of myelin, but the paraffin method could never start an erroneous theory by artificial cleavage of myelin, and I have also amply sufficient evidence of the cleavage of myelin

into large ellipsoids as well; and I may add, that almost all my specimens of nerves from different cases or experiments showing degenerative changes, numbering over sixty, were cut in celloidin as well as paraffin.

In Figure 6, I show regeneration of a nerve: the central ends of the axis cylinders have divided, and the newly formed axis cylinders may be seen in the Drawing. In both this Figure and Figure 3, the nerve fibre sheaths are greatly distended; and here, in Figure 6, the newly formed axis cylinders may be seen threading their way through the myelin droplets, formed probably round the original axis cylinder belonging to the nerve fibre. I believe, therefore, that inasmuch as these strands running from the axis cylinder to the periphery, guide in many cases the segmentation of the myelin, they also help in forming supporting structures for the regenerated axis cylinders. Drawing 3 was taken from one of a series of experiments on rabbits' sciatics, in which Descending Degeneration was brought about not by section, but by the application of strong Liquor Ammonia to the nerve, so that regeneration could be much more easily studied. I was indebted for the suggestion of Liquor Ammonia to Professor Münk of Berlin.

My conclusions are, that the fine strands seen in the Figures alluded to are far too numerous to be explained by the slits of Lantermann, and that while the slits of Lantermann are more probably dependent on the funnels of Golgi and Rezzonico, these fine strands are a supporting structure for the myelin in addition to the funnels of Golgi. These strands are present in the medullated nerve fibres of man, rabbit, and dog, and probably in many others, and are most easily observed when, by artificial means, aided by degenerative changes in the myelin, deposits of some kind, taking on various ground stains, are formed on them.

I do not believe the mode of segmentation of myelin just described is merely a later stage of the ellipsoid formation of von Büngner, Stroebe, and others. Still, I cannot formulate any definite theory to explain under what conditions in Descending Degeneration the cleavage I have referred to occurs, and not the ellipsoid segmentation of most writers. By the paraffin method both forms of segmentation may be seen; by the celloidin method, after the granular stage of Descending Degeneration is past, the

cleavage into ellipsoids always occurs. My impression is, that the segmentation into large ellipsoids may be artificial, the result of the action of reagents, and that the method of segmentation I have described may be the rule.

I should never have ventured to promulgate my theory were it not that long use of, and consequent faith in the method used emboldens me to do so; and I endeavoured as often as possible to compare the respective effects of chrome salts and osmic acid, celloidin, and paraffin on the same specimens.

Thirdly. I have to consider the evidence in favour of an epithelial membrane, probably situated between the myelin sheath and the neurilemma.

The usual theories as to the cells which act as phagocytes for the removal of the myelin, etc., in a degenerated fibre, are either that they are proliferated segmental cells or leucocytes. There seems to be little evidence of the entrance of leucocytes, although the theory has long been stated, but of the proliferation of segmental cells there is no question. The cells described as acting as phagocytes are, or become free inside the neurilemma.

Accepting the segmental cell proliferation theory, the segmental nuclei first enlarge, and the cell protoplasm also extends further round the fibre in every direction; and where a fibre is becoming distended it forms a sort of jacket, causing a certain amount of constriction. Proliferation follows, but it is not always very rapid. Karyokinesis may begin in these cells as early as the second day after nerve section according to Stroebe and others, but I have specimens which show a considerably later commencement of cell division. Stroebe describes karyokinesis as going on for fourteen days—from six to seven days most actively; and he agrees with Beneke that the cells so formed become free inside the nerve fibres, and act as phagocytes. These cells are the only cells described inside the nerve fibre, with the exception that Ranvier and others, as I have just mentioned, consider that leucocytes find their way into the interior of the fibre.

In a number of specimens of rabbits' sciatics, within a short time after ligature or section, I noted nucleated cells, which I believe are different from the segmental cells. They do not bulge to the same extent into the lumen of the fibre, their

nuclei are much smaller, and they may be seen (Figure 5) to form a sort of pavement-like epithelial membrane. This regular arrangement makes it difficult to believe that their appearance is explained by the granular balls of myelin, capped with segmental nuclei. Hertz, Tizzoni, von Frankl, Korybutt-Daskiewicz, Colasanti, Beneke, and Hanken describe granular balls full of myelin droplets, which they suggest may be greatly distended and degenerated segmental cells, but no cells such as I have found.

The appearances in the rabbit's nerves referred to suggested to my mind that the cells shown in Figure 5 were too regular for proliferated segmental cells, their nuclei too small, and finally, as Figure 5 clearly shows, segmental nuclei and the nuclei of these cells were seen markedly contrasted in the same fibre.

I have, with the utmost care, revised all the specimens from my experimental work, so as to clear up the nature of these cells. When it is remembered that in only seven days after ligature, and in the central end of the nerve—that is, above the higher of the two ligatures—these cells were seen, it must be admitted that a very surprising proliferation of segmental nuclei and an equally rapid absorption of myelin would have to occur in order to give the appearance seen in Figure 5. If karyokinesis does not occur in the peripheral end of a nerve after section sooner than the second day, and goes on, according to Stroebe, for six to seven days most actively, the proliferation would barely be accounted for, especially taking into consideration the large amount of granular protoplasm the cells possess, and the fact that they appear actually to fill up in course of time nearly the whole lumen of the fibres showing them.

These cells, more or less polygonal in shape, have granular-looking protoplasm and small, feebly stained nuclei, which colour far more feebly than even proliferated segmental nuclei do. Serial sections show that the cells bulge to a varying extent into the interior of the sheath, but in the nerve from which Figure 5 was taken they do not lie quite free within the neurilemma. Figure 5 shows the cells seven days after section of the sciatic, and is taken from the central end of the nerve, close to the wound, but it might represent the peripheral end of the nerve five or seven days after section or ligature. In many of my

experiments I divided or ligatured the sciatic in two places, and the middle portion often showed these cells better than the peripheral. I have been able to identify the cells three weeks after section in the peripheral end of the divided nerve, but beyond that period they were problematical. Where the fibres have become distended, as in Figure 3, a condition often noted near the experimental lesion, especially in the part of the central end of the nerve close to and evidently damaged by the injury, the smaller nuclei of these cells may be well seen and easily differentiated from the larger segmental nuclei (compare drawings 1 and 3).

In transverse section, the relationship between these nuclei and the neurilemma is obvious. They are closely applied to the inner surface of the neurilemma, and therefore lie between the neurilemma and the myelin sheath.

This cell membrane does not stain in a healthy fibre, is hardly recognisable in a degenerated fibre where the degeneration has existed for some time, and is only well seen in certain cases where the degeneration is sufficiently recent; and I have certainly noted that exudation favoured the staining and differentiation of the cells and nuclei.

This can be no artificial production; and I have endeavoured to show by the Drawings on Plate XV. that segmental nuclei cannot be responsible for the appearance alone, nor are these cells leucocytes. To such an extent eventually do segmental nuclei proliferate that it is difficult to state what nucleated cells occupy the old nerve fibre sheaths; but if these cells are not proliferated segmental cells, and not leucocytes, they must be the cells of a cellular membrane lying between the neurilemma and the myelin sheath, unstained and unrecognised in health, and only becoming observable when altered by pathological conditions. My belief is that they act as phagocytes, from the appearance of the cell protoplasm; but I am not aware of any analogous change in similar cells elsewhere, and the subject is well worthy of a more prolonged investigation by other workers.

In conclusion, I should add that Marinesco has described, as early as 1892, in the nerves of stumps, semilunar protoplasmic cells, either within or outside the neurilemma and found only in certain fibres, but they are not described as forming a continuous membrane.

DESCRIPTION OF PLATE XV.

Figs. 1 and 2. From the posterior tibial nerve of a case of diabetic neuritis, showing the funnels of Golgi and Rezzonico with the alterations produced in them.

Fig. 3. From the central end of a rabbit's sciatic thirty days after the application of strong liquor ammonia, shows distended nerve fibres with strands forming a sort of network (*n.k.n*). Axis-cylinders (*a*) may be observed in drawings 1, 2, and 3, with the myelin droplets arranged round the axis-cylinder; 4 and 5 show no axis-cylinder. Note the difference between the segmental nuclei (*s*) and the epithelial membrane nuclei (*b.n*); drawing 1 shows both. To the left-hand side of drawing 5, two normal-sized fibres are shown, demonstrating the fine strands running from axis-cylinder (*a*) to neurilemma (*p.s*).

Fig. 4. From a rabbit's sciatic after application of strong liquor ammonia, shows various stages of segmentation of myelin influenced by the fine strands referred to above. Note the pressure exerted on the axis-cylinders, and in the left-hand drawing only a congeries of myelin droplets is left.

Fig. 5. From the central end of a rabbit's sciatic seven days after double section. Specimen is close to lesion; shows the epithelial membrane (*b.n*). Contrast the small feebly stained nuclei of these cells with the larger segmental nuclei which are not nearly so markedly proliferated as might be expected.

Fig. 6. Regeneration of nerve fibres from a rabbit's sciatic six weeks after section, shows greatly distended nerve fibre sheaths (*p.s*) with newly-formed axis-cylinders (*r.a.c*) threading their way through the myelin droplets.

fu, funnels of Golgi.

fur, funnels of Golgi which have undergone alteration.

a, axis-cylinders.

n.k.n, neurokeratin (?) network forming periphery of myelin droplets.

s, segmental nuclei.

b.n, epithelial membrane nuclei between membrane and myelin sheath.

m, myelin.

p.s, neurilemma.

r, node of Ranvier.

c, connective tissue.

ax, fragment of axis-cylinder.

r.a.c, regenerated axis-cylinders.

ON THE STRUCTURE OF CROSS-STRIATED MUSCLE,
AND A SUGGESTION AS TO THE NATURE OF
ITS CONTRACTION. By W. M'DOUGALL. (*From the
Physiological Laboratories of St Thomas's Hospital and the
University of Cambridge.*) (PLATES XVI.-XXI.)

THERE has grown up during the last fifty years an enormous literature concerned with the structure and physical characters of cross-striated muscle, and with the phenomena of its contraction, and many suggestions have been made as to the nature of the processes by which this contraction is caused. Yet in regard to its structure widely different views are held by recent observers, while the very numerous observations on its physical characters remain for the most part as isolated, unexplained facts, and no suggestion as to the nature of contraction can be said to have been received as a working hypothesis by physiologists in general. In treating of the structure of muscle there seems to have been little or no attempt made to define the physical characters of different parts of the muscle fibres in the terms which we have learnt to apply to all non-living matter, namely, solid, viscous, gaseous, and liquid. But most authors have contented themselves with the use of terms which might be arranged in an ascending order of vagueness, from semi-solid and protoplasmic, through sarcous and spongioplasmic, to the 'zooid' and 'oecoid.' Most of the suggestions as to the nature of contraction attempt the explanation of one group only of the physical phenomena, and none have been based upon a knowledge of the structure of muscle. One author suggests that contraction is the result of the flowing of a liquid in some specified direction, another that it is caused by the 'contraction' of a protoplasmic network, a third that it is due to shrinkage of coagulating proteid, a fourth that it results from a mysterious exchange of place of discs of different composition, and a fifth that it consists in certain hypothetical evolutions of hypothetical electrically-charged particles. No hypothesis that I have come across, with the exception of that recently put

forward by Engelmann, can be said even to attempt to reduce the problem to one of mechanics.

Are we then to believe that living matter, which is being every moment built up from, and again broken down into, non-living matter, and which seems in very many respects to be subject to the known laws of physics and chemistry, is in this respect of the power of 'contraction' an exception to those laws, and therefore incomprehensible to our minds at the present time? Or can we find grounds for believing that the parts of living muscle are capable of the same classification as non-living matter, namely, into solid, viscous, and fluid substances, and that contraction and the definite pull exerted by a contracting muscle may be the result of work done on coherent structures by the force derived from the chemical energy of the substance of the muscle?

It has seemed to me that the best way of attempting to answer the latter question is to assume as a working hypothesis the truth of the proposition involved in it; and in investigating the structure of muscle, to interpret all appearances presented by muscle strictly in terms of the hypothesis, wherever such an interpretation seems possible. If this can be consistently done in every case, then we shall have advanced some way towards the conversion of our hypothesis into a tenable theory. It is, then, from this, which I venture to call a new standpoint, that I have attacked the problem of the structure of muscle.

The history and the present state of the controversy regarding the structure of the striated muscles of vertebrates and arthropods have been excellently summed up by Schäfer in his recent article on muscle (1).¹ The history has been rather fully given by Retzius (4) and Van Gehuchten (3) also. I feel, therefore, that it is unnecessary for me to give it again here, and I will only briefly summarise the present state of the question. As Schäfer points out, those who have dealt in recent years with the structure of muscle may be roughly grouped into two camps. Those of the one camp, among whom are Ramon y Cajal, Van Gehuchten, Melland, and Marshall, regard the striated muscle fibre as containing a contractile reticulum whose meshes are occupied by a more fluid substance. They seem to be biased by a desire to bring muscle into line with what is known as the network theory of cell-structure. Their chief argument appears to be

¹ A list of references will be found on the last page. The figures after the names refer to that list.

of the nature of "*Inductio per enumerationem simplicem*" from few and uncertain instances, and it is noticeable that their views are generally based upon preparations made by some one or two methods only. The observations recorded below will, I hope, render unnecessary any discussion of the views of these writers.

The observers of the other camp, among whom are v. Kolliker, Ranvier, Rollett, Rutherford, and Schäfer, maintain that the striated substance of muscle fibres of arthropods and vertebrates consists of coherent longitudinal elements (the muscle-columns of Rollett) embedded in, and more or less separated from one another by a granular protoplasmic substance which Rollett has called the 'sarco-plasm.' So far the members of this group are in agreement; but when we ask, "What is the nature of the muscle-columns?" we find the greatest possible diversity of opinions.

V. Kolliker regards the columns as bundles of very fine fibrillæ of homogeneous nature throughout their length ("*ursprünglich in ihrer ganzen Länge aus Einer und derselben Substanz gebildet, an welchen jedoch im Zusammenhange mit den Zusammenziehungen dichter (die dunkelen Stellen) und minder dichte Stellen sich ausbilden*").

Berry Haycraft (12), from the study of impressions made by pressing living and hardened muscle upon collodion, when it is beginning to set, has come to a similar conclusion, namely, that the longitudinal elements of muscle are homogeneous throughout their length, and that the appearances of bands and discs are, even in stained preparations, wholly due to variations in the diameter of these elements occurring regularly along their length.

Rollett (2), on the other hand, has come to an exactly opposite opinion. He holds that the muscle-columns in the living state present no variations in their thickness, and that the appearance of transverse bands and lines is due to regularly repeated, complex systems of layers of different substances which transmit light differently and stain differently with various reagents; and, further, that the appearance of differences in thickness of the columns is due only to these layers swelling or shrinking differently under the action of reagents. He describes the columns as corresponding to the areas of various shapes which can usually be seen to be mapped out by lines of sarco-plasm in transverse sections of muscle fibres, and believes that they are probably made up of fine fibrillæ packed together without any intervening sarcoplasm.

Nearly all authors who have dealt with the structure of striated muscle have described as two widely different types the wing muscles of insects on the one hand, and the ordinary skeletal muscles of vertebrates and arthropods on the other. The fibres of the wing muscles of many insects consist, as is well known, of slender cylindrical fibrils embedded in granular sarcoplasm in such a manner that each one is separated from its neighbours by a thickness of sarcoplasm about equal to, or rather less than, the diameter of the fibrils (*cf.* photo. 17). Schäfer (1), in a recent paper, adopts the view, which has been held by other observers also, that the fibrils are tubules regularly segmented by transverse septa, and he puts forward the suggestion that the

muscle-columns of other muscles, as described by Rollett, consist of some undetermined number of longitudinal elements, each of which is to be regarded as strictly analogous to the cylindrical fibril of the insect's wing muscle. He would strictly confine the term sarcostyle to the fibril of the insect's wing muscle, and to these hypothetical components of the muscle-columns of other kinds of muscle. Other authors have interpreted certain longitudinal striæ observed on these wing fibrils, after the action of reagents on them, as indications that they are bundles of still finer fibrillæ, comparable to those which Kölliker has stated to be the elements of muscles of the other type. Again, other authors have regarded the muscle fibres of insects' wings as a tissue 'sui generis' rather than as a specialised variety of cross-striated muscle.

Rutherford (15) has described the skeletal muscles of the crab as consisting of slender fibrils, the contractile elements, embedded in a non-contractile substance, and he regards these fibrils as regularly segmented. This description would therefore bring these muscles into line with the wing muscles of insects, and would tend to bridge over the gap between the two great types of striated muscle mentioned above.

Description of the Appearances presented by the Fibrils of the Wing Muscles of Insects.

Rollett (2) and Schäfer (1) have recorded that the above-mentioned fibrils of the wing muscles of insects may be seen to contract when isolated in white of egg, each segment going through a similar change in shape. (I have repeated this observation.) The segments of these fibrils appear then to be minute contractile structures, and it may be that they are ultimate contractile elements. I have therefore turned first to them in the hope of finding evidence of such a definite arrangement of parts as would constitute a machine. Schäfer describes these wing fibrils as membranous tubules, divided into segments by transverse discs, and containing fluid or viscous substances. In this description he is in agreement with numerous authors; and I shall show below that there are very strong grounds for accepting this view of their structure. Schäfer's drawings and photographs, which are made from fibrils after treatment with reagents, represent a very remarkable change in shape, resulting from contraction. Each of the segments is represented as having its end discs much increased in diameter, and its side walls bulged outwards, but at the same time much shortened. Other

authors have described similar changes, without offering any explanation.

Accepting for the moment the view that the segments are really membranous cylinders containing fluid substance, it is at once obvious that this change of shape, namely, an actual shortening of the side walls at the same time that they become bulged outwards, is an extremely curious one, and one difficult to account for in terms of our working hypothesis. For it is in the highest degree improbable that the essential and primary fact in the contraction of the segments is the shortening and bulging of the membranous side walls. It is, rather, almost certain that the bulging outwards of the side walls is caused by pressure exerted on them by the fluid contents, however this pressure may arise, whether it be a result of an expansive force generated in the fluid contents, or be caused by an approximation of the end discs of the cylinder by some unknown force, or in any other way. Of the steps by which the shape described as characteristic of the contracted state is arrived at, Schäfer (1) writes,—“it is a matter of the greatest difficulty to determine what those changes precisely are.” It seemed to me that the study of these changes must be of the first importance in any attempt to understand the structure of muscle; and since the actual contraction can only rarely be observed, the method I adopted was to examine very carefully fibrils in all the phases of contraction.¹ There was this point to be kept constantly in mind while observing the fibrils—that each segment of the fibril probably goes through its series of changes in shape without any but a very minute change in volume.

Now, we have seen that it is highly probable that the outward bulging of the walls is caused by the pressure of the fluid within the chambers, and in that case the curve of the wall in the longitudinal axis of the chamber must tend to be an arc of a circle. There is only one form of cylinder whose walls may be bulged outwards in this way, with a corresponding approximation of its ends, without there being produced in it any but a

¹ I have used throughout the course of my work the 2 mm. apochromatic homogeneous immersion objective of Zeiss, with compensating oculars, Nos. 6 and 12, and the achromatic sub-stage condenser. I would point out that it is quite impossible to make out the details described below with any inferior objective, such as the ordinary $\frac{1}{2}$ th oil immersion lenses.

very slight change of volume. Such a cylinder is one whose diameter is very nearly twice its depth.

When a slip from the mass of wing muscles of a wasp¹ is spread out in a drop of white of egg or normal saline solution, there are found numerous perfectly cleanly isolated parts of fibrils. Each of these appears as a delicate translucent cylinder, crossed at regular intervals by well-marked dark lines (α in photo. 1) and bordered by a faint halo of light. Although there are often fainter transverse lines to be seen between them, these lines can nearly always be readily distinguished. They have been rightly interpreted as the expression of transverse discs. It is by these discs that the fibril is divided into a longitudinal series of similar segments. (Schäfer (1) has called these segments 'sarcomeres,' and I shall use the name in the same sense.) When these transverse lines (which I shall call the lines α) are at distances apart of $4\ \mu$, the side walls of each sarcomere are parallel to one another, so that the whole sarcomere is a cylinder slightly more than $2\ \mu$ in diameter (photos. 1, 2, and 7). Sarcomeres presenting this appearance I regard as being in a state of extreme physiological relaxation or extension; for they are of frequent occurrence, and though in some sarcomeres the lines α are found at rather greater intervals apart, such are very rare, and it is always obvious that they have been violently stretched. The sarcomeres in this state of extreme relaxation I shall speak of as being in stage A. Each sarcomere is seen to have a dim ground-glass-like appearance at its middle parts, and to have at either end a narrow bright band. There can be very little doubt that this bright band is an optical effect produced by the highly refractive disc α , analogous to the bright halo surrounding a refractive granule seen by transmitted light. It is similar to the halo which borders the fibril in its whole length, but is better marked, *i.e.*, it is brighter and broader. Running through the length of each sarcomere, there can often be

¹ The following description applies equally well to the wing fibrils of the common bees and of the water-beetle, *Dytiscus marginalis*, and the absolute measurements given (which were mostly made upon fibrils from the bee with a micro-millimetre scale in the No. 6 ocular) apply equally well to them. The fibrils of the wing muscles of the common cockchafer and the common house-fly, and probably of all insects with small, rapidly moving wings, are almost exactly similar, except for slight differences in absolute size.

made out fine longitudinal striæ. These are best marked at the equator, and diminish in distinctness as they approach the discs α . If sarcostyles teased out in normal saline solution be carefully examined, and then a jet of steam be applied for a few seconds to the cover-glass of the preparation, and then the same sarcostyles be again examined, no change in the appearances can be seen. If, then, a little of Ehrlich's hæmatoxylin be introduced beneath the cover-slip and washed away after one or two minutes, certain details of structure are brought out more clearly. Photo. 1 was taken from a living fibril in normal saline solution, and photos. 2, 3, and 7 were taken from fibrils fixed and stained in this way.

After this treatment it can be made out that the discs α and the walls of the cylinders are stained. The discs α appear to be much more deeply coloured than the side walls. This appearance is due to two causes: firstly, the discs are thicker than the side walls, as can be seen by comparing optical sections of each; secondly, the discs are seen from above while standing on edge, and so the light transmitted by them has come through a considerable thickness (about $2\ \mu$) of coloured substance, while that which comes through the body of the sarcomeres passes only through two layers of the side wall, each of which is very thin, apparently only about $\cdot 1\ \mu$ in thickness. This second cause of the difference in the depth of colour is well illustrated by photo. 14, in which are shown a number of separated α discs stained with logwood. Some are seen lying flat in the field, and in them the colour is only just visible, and they appear, therefore, dim in the photograph, while some are seen standing on edge, and appear as very dark purple lines. The same photograph shows that the isolated discs seen on edge are bordered by refraction halos, thus confirming the interpretation, given above, of the bright borders of the α discs. In isolated fibrils the staining of the side walls can only be made out distinctly in those which are deeply stained. It is well seen in photos. 2, 4, and 5. In photo. 2 the colour can be seen to be most intense at the borders of the fibril where the wall is not seen as a simple layer, but is curved round so that the light comes through a greater thickness of it than it does in the middle line of the fibril. If the substance of the sarcomere were stained in

its whole thickness, then the colour would be most intense in the middle line of the fibril, that being the line along which the light must come through the greatest thickness of the substance. The study of transverse sections confirms the existence and the staining property of the delicate side wall. If a slip of the wing muscle of one of these insects be taken (preferably of the cockchafer, since in it the granules of the sarcoplasm interfere less with the transmission of the light than in most other insects), fixed by the application of steam, stained with logwood, and transverse sections made from it with the freezing microtome, the sarcomeres are seen in transverse section as tiny clear circular areas scattered more or less regularly through the darkly stained sarcoplasm, and in well stained sections each circle can be seen to be bounded by a thin line more darkly stained than the sarcoplasm (photo. 18).

That this dark line bounding each area is not merely an optical effect, analogous to the dark line which may be seen bounding a drop of oil in water, is proved by instances in which two or more areas are seen to be in contact with one another, and yet each is distinctly separated from the others by the darkly stained line. Such areas are shown in photo. 18. The wall seen thus in transverse section appears darkly stained, because the conditions are similar to those which cause the *a* discs to appear darkly stained in the isolated fibrils. The membranous wall of the sarcomeres can be best seen in partially disrupted fibrils. Photo. 8 shows a fibril in stage A, which has been torn in the process of teasing, so that part of the wall is laid out flat in the plane of the focus. It is well shown also in photos. 9 and 15. These disrupted fibrils were obtained by the following method. Slips of the wing muscles of the common house-fly are allowed to soak for some hours in normal saline solution and then teased out in water on the slide. A cover-slip is applied, and the water on the slide is suddenly boiled by holding the slide over a flame. Hæmatoxylin is then run under the cover-slip, and washed away after a minute or more. The fibrils are then found in various states of disruption. Many are completely broken up into discs, connected together only by irregular strands of delicate membrane, the remains of the side walls. Photo. 14 shows the appearance of the discs, but no

shreds of the membranes are clearly seen in this field. Others seem to be split open along one (photo. 8) or two opposite edges (photo. 9), and lie as flattened, crinkled membranes in one plane.

In fibrils fixed in stage A by steam and stained, the longitudinal striation of the sarcomeres is much more clearly marked than in the living fibrils (photo. 2), and it can now be made out that it is on the surface of the fibrils only; for on focussing from above downwards very carefully, the striæ come into view as the mid-line of the upper surface is reached, and are best seen at a focus slightly lower than this; when the middle of the thickness of the sarcostyle is reached they cannot be seen, but can sometimes be made out again at a still deeper focus. I believe that they represent longitudinal foldings in the delicate wall of the sarcomere. Their appearance in stained fibrils is exactly that which must be produced by folds in the wall most marked at the equator (photo. 2). This is still better shown in such fibrils as that in photo. 8, where part of the wall is torn and spread out flat. The spread-out part can then be clearly made out to be a delicate, highly refractive membrane, folded longitudinally between each pair of α discs. We shall see that the diameter of the sarcomere becomes very much increased at its equator during contraction; and unless the wall be very readily extensible, some such folding of the wall is necessary to allow the increase in diameter to be effected.

In correspondence with this is the fact that, as the wall bulges outwards during contraction, the longitudinal striæ become less and less marked, and in the later stages of contraction are no longer visible. The final proof of the existence of the foldings in the wall is afforded by the study of transverse sections cut with the freezing microtome from slips of the muscle fixed in the fully extended condition by steam, and stained deeply with logwood, either before cutting or on the slide. Although the refractive granules of the sarcoplasm make the walls of the sarcomeres very obscure in some fields, in others it can be clearly seen that the walls of a large proportion of the sarcomeres are not even circlets, but have deep foldings corresponding to the striæ seen on the isolated fibrils (photo. 16). In transverse sections of partially contracted slips prepared by the same

method, less marked foldings can be seen (photo. 17), and in sections of much contracted muscle the walls are seen as even dark circlets (photo. 18).

The membranous character of the wall is well shown in photos. 8, 9, and 15. In these fibrils, some of which have been torn by teasing, and others burst by boiling in various stages of contraction, parts of the wall can be seen spread out as crinkled membranes. Their character can, of course, be made out more certainly under the microscope, when one can easily prove by careful focussing that the objects represented in the photographs really are very delicate membranes.

In studying the staining properties of the fibrils I have relied chiefly on Ehrlich's hæmatoxylin. (It is this preparation of logwood to which I refer when no other variety is specified.) But I have stained them also while living with logwood dissolved in distilled water, and with methylene blue, and after fixing by steam, with eosin and Delafield's hæmatoxylin. With all these methods of staining the results are similar to that produced by the use of Ehrlich's hæmatoxylin.

This tediously minute description of the sarcomere in the fully extended state, stage A, may, I think, be said to have established that it is a cylinder bounded by membranous walls, and shut off from its neighbours in the fibrils by transverse membranous discs, which, though thicker than the side walls, resemble the substance of the latter in optical and staining properties; and further, that the side walls are thrown into longitudinal folds, which are deepest at the equator, and fade away towards the ends of the chamber. It seems highly probable that the chambers contain fluid or viscous substance which is coagulable by heat, does not stain with logwood, and escapes if the walls of the chambers be torn before it is coagulated.

A sarcostyle in this fully extended state corresponds to the conventional description of the appearance of striated muscle fibres, for it shows an alternation of broad dim bands and narrow light bands, each of the latter being crossed at its middle by a dark line. I shall go into the question of a difference of substance constituting the dim and bright bands later, but would point out here that there is no need to assume any such differentiation to account for the bands. In the production of

the appearance there are two factors chiefly concerned: (a) the disc α throws on either side of itself a bright halo, and so the parts between the halos are dim by comparison; (b) the foldings of the highly refractive wall, which are most marked at the equator of the sarcomere, must interfere most at that part with the passage of the light. After staining with haematoxylin the dim band is more marked, because the light has now to pass through the stained folds of the wall.

In a teased preparation of the living muscle other sarcostyles may be found in which the discs α are from $3-3\frac{1}{2} \mu$ apart (see fig. 1). The total width is increased, and is now about 3μ , but

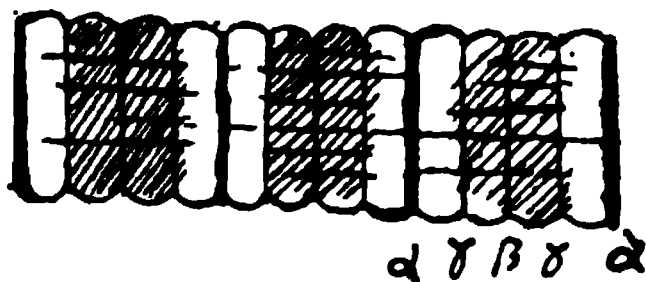


FIG. 1.—Three sarcomeres in stage B.¹

the side walls are exceedingly difficult to make out. The longitudinal striæ are still seen on the surface, and there are now visible three faintly marked transverse lines between each pair of lines α , dividing the length of each sarcomere into four equal zones. These, too, are surface markings, so that the surface of each sarcomere now appears marked out into tiny rectangular areas. By very careful focussing there can sometimes be made out an appearance of a tiny bulging of the wall between each pair of transverse lines, but this is so minute a detail that one would not accept it as a true picture of the side wall, were it not made highly probable by analogy with the sarcomeres in the same stage of contraction in other kinds of striated muscle, and with a later stage of contraction of these sarcomeres. I shall speak of the three transverse lines as γ, β, γ (β being that one at the equator of the sarcomere), and of sarcomeres in this state as being in stage B of contraction. Photo. 3 represents sarcomeres at this stage, stained with logwood. I have not succeeded in obtaining a good photograph of living fibrils in this stage.

In sarcomeres in which the discs α are at intervals of only 3μ or slightly less, the lines $\gamma \gamma$ are less well marked, while β is better marked, and the appearance is that of figure (2). The

¹ These figures 1, 2, 3, and 4 are made after drawings from living sarcostyles, and are semi-diagrammatic.

outline of the wall can be clearly seen to form a double curve between α and α , being drawn in where β meets it, but not quite so deeply as at α . No distinct break in the curve can be made out at the point at which the line γ meets it. Photo 3 represents a steamed and stained fibril in this stage.

When the discs α are at intervals of not more than 2.5μ the lines $\gamma \gamma$ can no longer be seen, but β is still better marked than before (see fig. 3). The outline of the wall on either side of each sarcomere is that of a pair of almost semicircular curves, standing upon chords which run outwards from the ends of α to

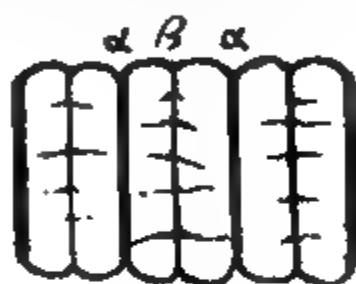


FIG. 2.—Three sarcomeres in stage between stages B and C.

FIG. 3.—Three sarcomeres in stage C.

the ends of β , being more or less oblique to the axis of the sarcomere. The degree of obliquity is slightly variable. The longitudinal striæ can still be made out crossing the line β , and extending a little way to either side of it. There is no longer any dim band, for the refraction halos of the discs α now light up the whole depth of the sarcomere. The width of the sarcomere is about 3.5μ . I shall speak of sarcomeres in this state as being in stage C. Photo. 5 represents such sarcomeres.

The lines $\gamma \gamma$ and β in living fibrils seem to be the optical effects of annular constrictions in the wall of the sarcomere at these levels, for they vary in visibility with the depth of the dip in the outline of the wall at the same levels, and are surface appearances only. On focussing very carefully downwards through a sarcomere in stage C, the line β disappears entirely when the middle of the thickness of the sarcomere is reached, and reappears at a slightly deeper focus.

In sarcomeres in which the discs α are slightly nearer to one another the lines β are less marked, and when the discs α are at intervals of only 1.7μ the lines β are only very faintly marked. The outline of the sarcomere no longer forms a dis-

tinctly double bulging between α and α , but rather a single flattened curve, very slightly indented where the line β meets it (see fig. 4). In fibrils in which the discs α are very slightly nearer together than 1.7μ the lines β can no longer be seen;

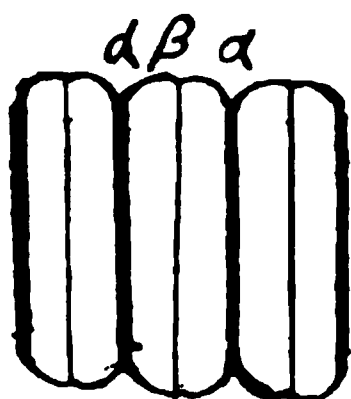


FIG. 4.—Three sarcomeres in stage between stages C and D.

and in each sarcomere the side wall, which is now less than 2μ in length, is seen in optical section as a simple, rather flattened curve, joining the ends of the lines α (photo, 12). There cannot be seen any trace of the longitudinal striæ. The width of the sarcomeres is about 4μ . I shall speak of this as stage

D. Contraction may proceed even slightly beyond this stage, for sarcostyles are found in which the lines α are at intervals of scarcely more than 1μ , and the width of the fibril is nearly 5μ . Such an extreme degree of contraction is rarely to be observed, and is generally restricted to a small part only of a sarcostyle. I shall call this stage E.

Although I have not observed all these stages of contraction in any one sarcostyle, I have seen stages A, B, and C in different parts of one sarcostyle, and, again, stages B, C, D and E in parts of one sarcostyle. In such cases there is generally traceable a very gradual transition from a part in one stage of contraction to one in another stage.

Interpretation of the above Appearances.

If we compare a sarcomere in stage A with one in stage E we see that there has been produced during contraction a very remarkable change in shape, such as has been described by authors, but even more extreme than has usually been represented. The hollow cylinder 4μ long by 2.2μ in diameter (α in fig. 5) has become such a figure as would be described by revolving the plane figure b (fig. 5) upon its vertical axis. The approximation of the discs α represents a contraction in length of about 75 per cent. I have made a great number of very careful measurements of the sarcomeres in each of the stages of contraction that I have described above. It is, of course, easy to measure the length accurately; but the width cannot be measured with

greater accuracy than to about $\cdot 3 \mu$. On working out the volume of the sarcomere at each stage of contraction by the

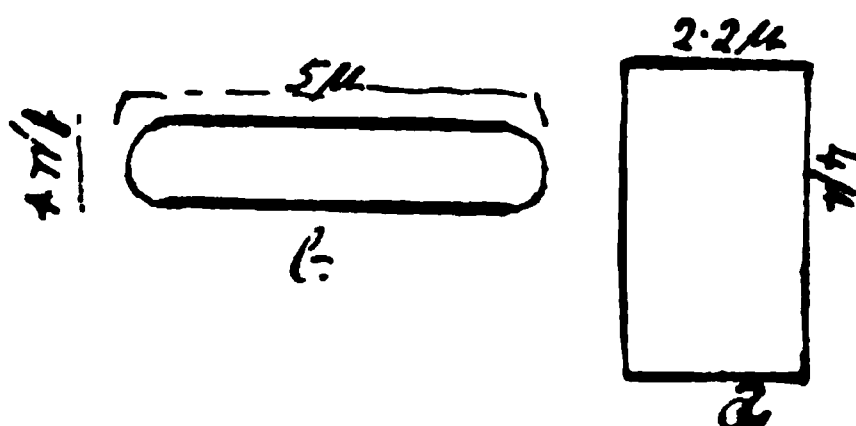


FIG. 5.—Outlines of sarcomeres in stages A and B.

formula $l \pi r^2$, I find (using the figures given above, which are the means of many measurements),

| | | |
|------------|-------------|---------------|
| In Stage A | volume = 15 | cubic μ . |
| „ B | „ = 21 | „ |
| „ C | „ = 15.3 | „ |
| „ D | „ = 21 | „ |
| „ E | „ = 19 | „ |

But in these calculations I have taken each sarcomere as a cylinder, and in the case of all, except stage A, the volume found is therefore slightly too large, for their walls are constricted at one or more levels. Then if a small deduction be made from each of the volumes found for the sarcomeres in stages B, C, D and E, the figures are so nearly the same that, although there seems to be a slight increase in volume, the deviations from the mean fall well within the margin of error of observation, as we should have expected from obvious theoretical considerations. This result is not of any great value as affording evidence of change, or absence of change, in the volume of the sarcomeres during contraction, but it proves that the limits of the sarcomeres, *i.e.* the discs α , have been recognised correctly in all the stages.

In order to explain this series of changes in terms of our working hypothesis, it seems necessary to infer the existence of certain structures disposed in a certain manner within each sarcomere; and I can conceive of no other arrangement and structure of parts which would give rise to the changes in appearance that I have described, when by any means the discs

α are approximated to one another. I will first state what these structures and these arrangements are, and will then bring forward direct evidence of their existence.

If the side wall and the end discs α of the cylindrical tubule, the sarcomere of stage A, are of inextensible, or only very slightly extensible, membrane, and if it is crossed by three transversely disposed elastic discs attached at their periphery to the wall, and dividing the sarcomere into four equal chambers, and if the middle one of the three discs be less easily extensible than the other two, then there is an arrangement which must bring about all the changes in appearance and dimensions that I have described above, whenever by any force the discs α at the ends of the sarcomeres are approximated. (Elastic bands in the substance of the wall would produce similar results.) For if there be such an arrangement, the extended sarcomere consists of four equal cylinders, joined end to end, each being $1\ \mu$ in depth and rather more than $2\ \mu$ in diameter. Now, a cylinder whose side walls will bulge as arcs of circles, its ends being correspondingly approximated, without change in volume,¹ is one whose diameter is approximately twice its depth; and in one whose diameter is slightly greater than twice its depth, such a change in shape will result in a diminution of volume. If there are such discs, γ, β, γ , as suggested, the sarcomere consists of four cylinders of this latter kind, joined end to end. If any force tends to approximate the end discs, there will be produced a fluid pressure within the sarcomere, which will seek relief by pressing upon the side walls. It is easy to show by a simple geometrical diagram that such a fluid pressure must tend to cause the side walls to bulge as arcs of circles (seen in longitudinal section). If, then, the chambers be bounded on every side by inextensible membranes and filled with incompressible liquid, the change in shape cannot take place. But by reference to the diagram (fig. 6) it will be seen that each chamber of the sarcomere has one easily extensible end disc γ . This, then, will be stretched, and by thus compensating for the tendency to diminution of volume, allow the change of shape to be effected. That the stretching of the elastic disc, forming the septum between

¹ There would be at first a slight increase in volume, and later an equal diminution, but this does not affect the argument.

any two of the chambers, will tend to cause an increase in volume, is easily seen by considering the diagram (fig. 7). It

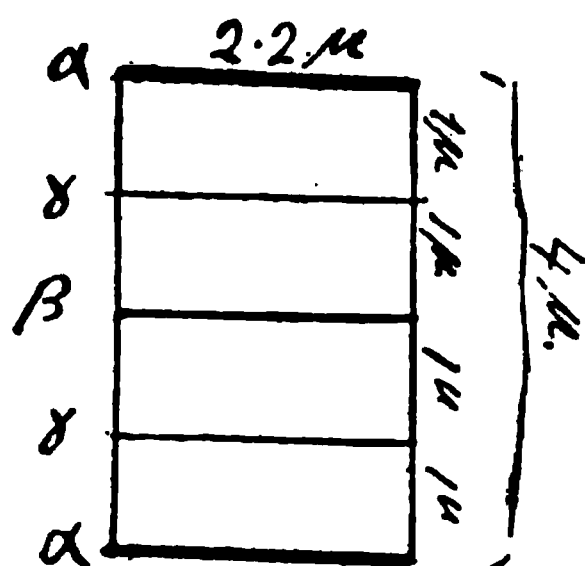


FIG. 6.—Diagram of extended sarcomere.

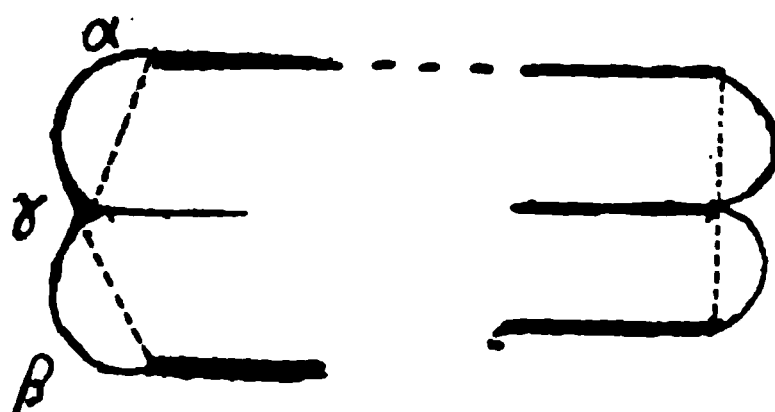


FIG. 7.

represents the outline of the wall of two of the chambers having the elastic end disc γ in common. On the right is shown the outline which would result if the disc be not stretched, on the left the effect on this outline of the stretching. The effect is that the two chambers behave more like one whose diameter equals its depth, and in such a chamber the bulging of the wall would result in a considerable increase of volume.

As the discs α are brought still nearer to one another, the bulging of the segments of the wall of each sarcomere must increase until the outline of each approximates to a semicircle, and the discs γ must be more and more stretched, so that the chords on which these curves stand become more and more oblique. The bulged walls of neighbouring sarcomeres must then come into contact where they meet at α ; and as the discs γ stretch more and more, these parts of the walls will become flattened out against one another, and being pressed together by the fluid pressure within the chambers, will seem to produce the ends of α to

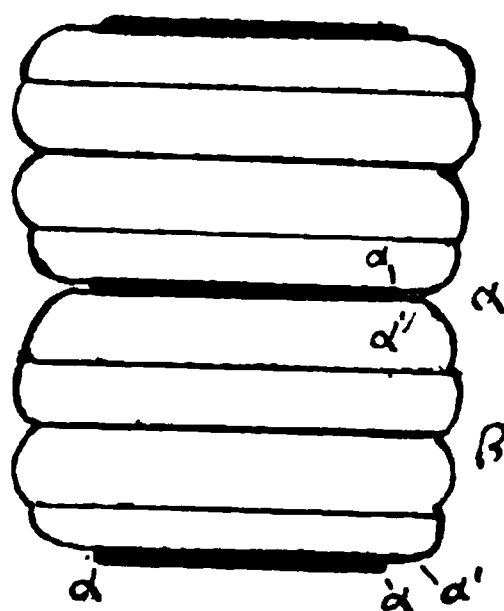


FIG. 8.—Diagram to illustrate the production of fig. 2.

α' as in fig. 8. If the disc β were inextensible, then the same process would occur at its ends; but it appears to be just so readily extensible as to obviate any coming into contact

of the segments of the side wall at its periphery. This, then, appears to be a possible explanation of the lengthening of the discs α and the shortening of the side walls of the sarcomeres, as represented by authors, and of the other changes in shape that I have described in the early stages of contraction.

As contraction proceeds, α and α come nearer together, the side walls are taken up by this rolling-out process more and more, and are added to the periphery of the transverse α discs, and the discs γ and β and γ must go on stretching, to compensate for the tendency to diminution of volume. The double curve of the wall between α' and β will then become a single flattened curve and the constriction caused by γ in the earlier stages will no

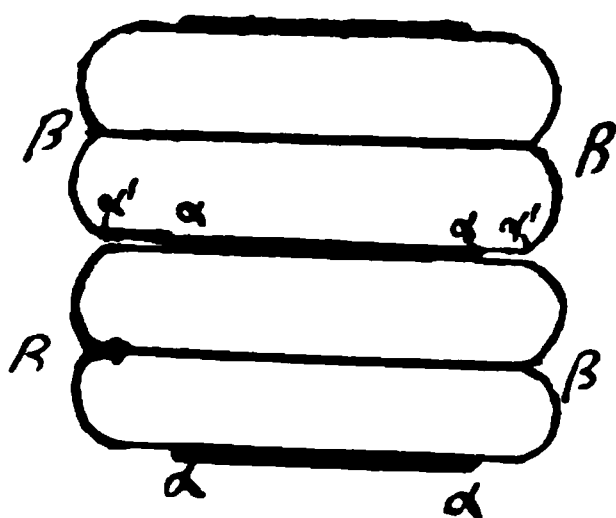


FIG. 9.—Diagram of stage C.

longer be present, and the lines γ , which are the optical expressions of the constrictions, will no longer be seen. The appearance of stage C is thus produced. The sarcomere now appears to consist of two chambers, each of which is about 1.25μ in depth and 3.5μ in diameter; and if the end walls be still further approximated, the disc

β must stretch more and more to accommodate the liquid contents, and the rolling out of the walls at α' must go on still further. The constriction caused by the disc β will therefore become shallower, and its optical expression, the line β , become correspondingly fainter, and so the appearance of stage D is produced. When contraction goes beyond this stage, the constriction caused by β is quite obliterated, the wall bulges in an even semicircular curve between α' and α' , and the appearance of stage E results.

The question at once arises, Is the length of the side wall of the extended sarcomere sufficient to play this double rôle in the fully contracted sarcomere? In the latter state about 1.5μ , or a little more, forms the curved side wall, and 1μ of either end is incorporated with the transverse discs α and α , as can be seen from the diagram (fig. 10). The original length is 4μ , so that this rough calculation shows that its length is sufficient to allow it to play the part that I have attributed to it. If this inter-

pretation be the true one, the dark transverse lines at α in the contracted sarcostyle represents discs of each of which the central part is the disc α , and the peripheral parts a double layer of the side wall. The side wall, as we have seen, is very similar in appearance and behaviour to the substance of the discs α , and it has not more than half the thickness of the discs. In some cases, when a partially contracted sarcostyle is watched while being stained with hæmatoxylin, the discs α seem to take the stain more rapidly than the side walls, and then it can sometimes be seen that the middle part only of the discs is stained, the heterogeneous nature of their parts being thus brought out. The fibril shown in photo 9 affords, I believe, further illustration of this process. The water in which it lay

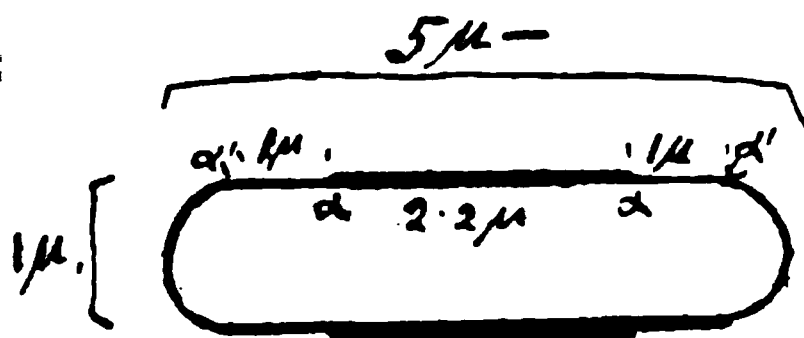


FIG. 10.

was suddenly boiled, and the walls of the sarcomeres seem to have been burst open irregularly along either side, and the flaps of wall to have been thrown outwards by the force of the bursting, so as to lie in the same planes with the discs α , β , and to appear to produce them at either side.

In the wing fibrils of the wasp, bee, and water-beetle I could find for a long time no direct evidence of the existence of transverse discs at γ , β , and γ . For although, when the walls are stained with logwood, the lines at γ , β , and γ are accentuated, and the β line may appear very darkly stained (photo. 5), yet this may well be due merely to the stained substance of the wall being seen in oblique optical section at the constrictions, so that the light comes through a greater thickness of the walls at these levels; and the visibility of the lines varies in both living and stained fibrils with the degree of constriction of the wall at the same level. (Cf. photos. 4, 5, 6, and 12.)

On examining fibrils from the wing muscles of the common house-fly, direct evidence of the existence of discs stretching

across the sarcomeres at the levels of the lines γ , β , and γ was at once found. The sarcomeres of these fibrils are not so constant in absolute size as those described above (though the proportions of their parts are exactly the same), and in many of the fibrils in stage A the sarcomeres have the shape of a pair of truncated cones put base to base (photo. 7). But the most striking difference is that crossing the middle of each sarcomere is a thin dark line, bordered on either side by a bright halo, the appearances at all foci being exactly like those produced by the disc α , except that both the line and its bright borders are narrower and less marked (photo. 1). When such a fibril has been steamed and stained with hæmatoxylin the presence of a disc corresponding to the line β is proved by the fact that the darkly stained line can be focussed through the whole thickness of the sarcomere, just like the dark line which is the expression of the disc α (photos. 7 and 10), and in later stages of contraction also it can be focussed through the thickness of the sarcomere in the same way. I have not succeeded in finding isolated β discs, but this is not surprising if we remember that they are still more delicate than the α discs, and that the latter, when seen lying flat, are, though stained as deeply as possible, only very pale and dim (photo. 14).

These fibrils, when steamed and stained in stage A, afford also direct evidence of the existence of discs corresponding to the lines γ . In photo. 7, taken from such a fibril, there can be seen midway between the α and β discs a very fine, dark, transverse line, which under the microscope can be focussed through the whole thickness of the sarcomere, and is distinctly coloured by the stain. Since the wall is not constricted at the level of these lines in this fibril, the line must be simply the optical expression of a very delicate transverse disc. In photo. 10 the β and γ discs are still better shown, and in it the β discs appear as well marked as the α discs. Photo. 11 shows the appearance of another part of the same fibril where it is slightly contracted. (This is not the typical appearance of a fibril in stage B, which is shown in photo. 3, but, as in the fibril of photo. 4, the discs seem to have exerted less than their usual constricting action in proportion to the distending force, so that the constrictions at γ and β are very little marked in photo. 11

and in photo. 4, that at γ not at all, though that at β is very well shown. Such slight variations from the typical form are not uncommon in any stage of contraction.)

In some of the sarcomeres in this photograph it can be seen that the γ disc is bowed slightly with its convexity towards the β disc. It is obvious that, if these discs form complete septa across the sarcomere, shutting off the fluid in each compartment from that in the others, the γ discs must become bulged towards the β discs when the sarcomere assumes the shape of those in the photograph, and in all the later stages of contraction.

I shall show below that in investigating the structure of the muscles of the crayfish I have found similar direct evidence of the presence of discs exactly corresponding to the α , γ , and β discs of these insects' wing fibrils; and in all the different kinds of cross-striated muscle that I have examined, I have found indirect evidence of the existence of corresponding structure in constrictions occurring at the corresponding levels in the muscle columns. It seems, then, highly probable that there really do exist elastic discs such as it was found necessary to assume the existence of in order to explain the changes of shape exhibited by the sarcomere during contraction.

*Appendix to the above account of the Structure of the
Wing Fibrils.*

Since the above account was written, I have obtained further confirmation of its accuracy in respect to several important points.

I have been able to see very distinctly in living fibrils teased from the wing muscles of the house-fly, and lying fully extended in normal saline solution, delicate transverse lines midway between the α and β discs, and these are the optical sections of the γ discs. I have seen them still more clearly in fully-extended fibrils which had been teased out in water and allowed to become dry through the evaporation of the water from under the cover-slip.

I have also seen the γ and β discs stained equally darkly in fully-extended fibrils from wing muscles of the water-beetle,

which had been fixed in 93 p.c. alcohol, and then soaked in glycerine and stained with logwood.

The method of negative gold-staining which will be described below affords further confirmation of the presence of the discs, for by this method the contents of each of the four chambers of the sarcomere may be stained. In sarcomeres in stage A it can then sometimes be made out that the discs γ , γ , and β , as well as the disc α , remain unstained, and can be seen as fine bright lines, dividing the stained contents of each sarcomere into four equal masses. In other cases the discs themselves become stained by this negative gold process, while the contents of the chambers of the sarcomere remain unstained, or only very slightly stained. I have observed all the discs stained in this way in fibrils from the wing muscles of the water-beetle, house-fly, and wasp.

If fibrils fixed in the fully-extended state by strong alcohol be teased out and watched, while 25 p.c. formic acid is run under the cover-slip, it can sometimes be seen that each sarcomere swells out rapidly at its equator, until its wall forms a single, almost semicircular curve between the ends of the sarcomere,

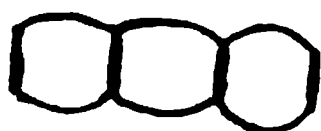


FIG. 11.

where it remains attached to the α discs (see fig. 11). The sarcomeres shorten to a corresponding extent as this bulging of the wall takes place. In such cases it is clear that

while the delicate γ and β discs are so affected by the treatment, probably by the acid, that they exert no constricting effect upon the side walls, yet the α discs remain of their normal width, namely, 2.2μ . The α discs, then, are not only more resistant than the others to the action of the acid upon them, but they are inextensible by such tension as is exerted by the walls as they bulge under the swelling action of the acid on the contents of the chambers. Fibrils presenting the moniliform appearance produced in this way are frequently found in preparations by the negative gold method.

Similar evidence as to the character and functions of the discs may be obtained by treating living fully-extended fibrils with .3 p.c. formic acid. I have observed a fibril in stage A rapidly contract to stage C as the acid, which was allowed to run under the cover-slip, first began to act upon it, and then, when the acid

had acted on it for a few seconds longer, each sarcomere suddenly bulged outwards, the constrictions of its wall becoming obliterated and its length increased as it assumed the moniliform shape shown in fig. 11. The interpretation of these changes seems to be, that the contents of the sarcomere swelling, under the action of the acid, exert a pressure on the walls which causes the preliminary shortening, and that then the γ and β discs become disrupted by the acid and cease to exert their constricting action, while the α discs remain unaffected. The sarcomere then assumes the form which gives the greatest capacity, the free bulging of its walls being no longer restrained by the γ and β discs.

*On the Appearances presented by Fibres of the Leg Muscles of
Dytiscus marginalis.*

It is well known, from the descriptions given by Rollett and other authors, that transverse sections of fibres of the leg muscles of this beetle, stained with gold chloride, usually present a narrow central band of granular stained substance, which may be a simple linear band, or has frequently a $\rangle\text{---}\langle$ shape, or presents more irregular arms running towards, but never reaching, the periphery (photo. 35). This is the section of a central core of protoplasmic substance, in which one or more longitudinal chains of nuclei are embedded. In the transverse section there radiate out from this central band to the periphery of the fibre darkly-stained lines, which mark out the surface of the section into narrow unstained areas. The stained substance occupying the central core and forming the radial lines seems to resemble very closely the sarcoplasm of the wing muscles in its function and properties, except that its granules are much fewer and smaller, and it has been suitably called by the same name.

The narrow unstained radial areas marked out by the lines of stained sarcoplasm are transverse sections of the muscle columns, about the nature of which there is so much diversity of opinion.¹

¹ The sarcoplasm stains darkly not only with gold chloride but also with logwood after fixation with steam, chromic acid, formaline, or Flemming's

If a slip from the leg muscles of the beetle be pinned out in a condition of complete extension, *i.e.*, as much as or slightly more extended than it is in the body when its antagonists are well contracted, and be fixed in this condition by the application of steam or by soaking in formaline or chromic acid, and then the longitudinal surface of the fibres examined, it is seen (photos. 19, 20) that the surface is marked by parallel longitudinal lines of granular sarcoplasm, separating narrow brighter areas corresponding in width to the brighter unstained areas described in the transverse section. These narrow bright areas are the edges of the muscle columns presented at the surface of the fibre. In the living or steamed fibre they are about $1.4\ \mu$ wide.¹ If the fibres be stained lightly with logwood, the sarcoplasm becomes coloured, while the greater part of the substance of the muscle columns remain uncoloured. By focussing downwards from the surface of a fibre, the lines of sarcoplasm can then be shown to be the optical sections of continuous flat sheets of sarcoplasm radiating from the central core, and separating from one another the plank-like muscle columns. The latter have their flat parallel surfaces applied to those of their neighbours on either side, though separated from them by the thin planes of sarcoplasm (*cf.* fig. 12 and photos. 20 and 35).

fluid. In making my preparations I have found the first three methods of fixation by far the most useful. Since it is easy, as I shall show below, to see in living muscle fibres all the normal appearances characteristic of the different stages of contraction, it is possible, by comparing with the living fibres, fibres fixed by any reagent, to make out accurately the effect of the reagent on the parts of the fibres. This can be done best of all in the case of fixation by steam; for if a few fibres be spread out in normal saline solution and carefully examined, and then a jet of steam be applied to the cover-glass for a few seconds, and the same fibres again examined, it can be seen that, just as in the case of the wing fibrils, the normal appearance of the living fibre is preserved unchanged. Of all other reagents I have found a 10 p.c. solution of Scherer's formaline and a .2 p.c. solution of chromic acid to be the best fixing agents. The former does not preserve the normal relation of the sarcoplasm and the muscle columns in every case with such absolute certainty as does the latter, but it causes very much less shrinkage than the chromic acid or any other chemical fixing agent that I have used. Fixation with the method of staining fresh tissue with gold chloride is uncertain: it is sometimes true, but often untrue. Alcohol very seldom preserves the normal arrangement of parts, and it causes very great shrinkage.

¹ The measurements given here and below apply to the great majority of the fibres of the leg muscles. But in the muscles of the first and second pair of legs there occur some fibres of rather coarser structure, though the proportions of the parts are the same as in the others (photo. 19).

In fibres in this fully-extended state the cross-striation is but little marked. With a lens of medium power there is seen an appearance of narrow, faintly brighter transverse bands occurring at regular intervals. With the lens of high power it becomes apparent that this is due to septa disposed transversely across



FIG. 12.—Diagram of a fibre cut across transversely, and showing both longitudinal and transverse surfaces.

each muscle column at intervals of $5\ \mu$ along its length. Each one of these septa appears in optical section in the longitudinal view, which we are now considering, as a well-marked dark line, having on either side of it a band of brightness about $7\ \mu$ in width. This septum stains darkly with logwood (photos. 20 and 22), and seems to be, as I shall show below, in every way strictly analogous to the α disc of the wing fibrils, and the bright band on either side of it seems to be a halo effect, due to the highly-refracting nature of its substance. I shall therefore speak of it as the α septum. The α septa occur in each muscle column of a fibre in this extended state at intervals of $5\ \mu$ with the greatest regularity, and in all the columns of a fibre they are usually

arranged at the same transverse levels, so that through optical fusion of their halos they produce the appearance of narrow bright bands across the fibre. Sometimes in the living fibres, but more frequently in fixed and teased fibres, the regularity of the cross-striation is destroyed through the dislocation of some of the columns longitudinally, so that the α septa no longer occur at the same transverse levels, but form a stair-like series across the fibre, or have some still more irregular distribution. Each muscle column is then divided by the transverse α septa into a longitudinal series of segments. It will greatly facilitate the description of these fibres if I anticipate the conclusion to which the investigation of their structure has led me, by saying that the muscle columns of these fibres appear to be strictly homologous in structure and function with the sarcostyles of the insects' wing muscles, and that their segments correspond point for point with the sarcomeres of the latter. I shall therefore speak of these fully-extended muscle columns whose α septa occur at intervals of $5\ \mu$ and whose surfaces are plane, as being in stage A. They cannot be isolated in the living state as can the sarcostyles of the wing muscles, for, owing to their shape and the smallness of the amount of sarcoplasm between them, they adhere together much more closely than do the cylindrical sarcostyles embedded in a relatively large amount of sarcoplasm. Nevertheless, they can be readily isolated by careful teasing from fibres fixed in the extended condition by formaline or chromic acid, and best of all by a watery solution containing .2 p.c. chromic acid and 1 p.c. formic acid. Photo. 21 represents muscle columns in stage A partially isolated in this way. In photo. 21 there can be seen the edges of three lamellar columns with the intervening sheets of stained sarcoplasm; these lamellæ are curved and twisted so that at a deeper focus their flat surfaces lie in the plane of the field. The flat surface of another column is shown at * in photo. 21. On examining the flat surface we see the darkly-stained transverse lines, the expression of the α septa, and on either side of each of the lines the band of light $.7\ \mu$ wide. The surface of each segment can be seen to be thrown into longitudinal wrinkles. This, as I shall show below, is due to the shrinkage caused by the chromic acid. Another good method for obtaining short lengths

of isolated muscle columns is to cut, with the freezing microtome, transverse sections of fibres fixed in stage A with chromic acid or Flemming's fluid; if then glycerine and a cover-slip are applied, and the latter is tapped and rubbed to and fro over the sections with gentle pressure, many of them become completely broken up into the short lengths of muscle columns which may be seen in all positions. The larger fragments of fibres obtained in this way and by teasing consist of a variable number of muscle columns still adhering together; and then, according as the flat surface of one of them or the edges of the group are presented, there are seen simply the transverse lines α and the longitudinal wrinkles more or less marked (as in photo. 21), or the narrow edges of the columns crossed by the α lines and separated by the dark lines of sarcoplasm (as in photo. 20). Frequently such a piece may lie so obliquely in the field as to show both the longitudinal surfaces to slightly different foci, *i.e.*, it is seen like a closed book held obliquely towards the eye, so that both the cut edges of the leaves and the flap of the cover are seen at once.

If a slip of the muscle be pinned out as before, but in a slightly less extended condition, and fixed by the same methods as before, it is found on inspection of the longitudinal surfaces of the fibres that the lines α are at smaller distances apart than $5\ \mu$. The sarcoplasm is now no longer spread out in thin sheets between the radial lamellar muscle columns, but is accumulated in radial lines, at levels which correspond to constrictions in the muscle columns. Since the sarcoplasm is relatively opaque, the distribution of these lines plays a very large part in the causation of the transverse striation, especially when the sarcoplasm is stained with gold or logwood.

In parts of fibres which are slightly contracted, and in which the α septa are at intervals of about $4\ \mu$, the sarcoplasm is accumulated at the levels of the α septa and at three equidistant levels between each pair of them. The muscle columns come into contact with one another at the intermediate levels, but their planes of separation can be traced as fine longitudinal lines, and the sarcoplasmic accumulations appear as tiny dots or thickenings upon these lines. Even at this stage it can be seen that these dots are diamond-shaped, with one axis transverse and

one longitudinal. Photo. 22 represents a fibre in this stage of contraction: it was taken from a fibre of the muscle isolated in normal saline solution, and simply fixed by steam applied to the cover-glass. The lines α are now optically fused with the dots of sarcoplasm at their levels to form dark transverse lines, on which the dots form thickenings at regular intervals of about 1.5μ . Their refraction halos light up, on either side of this line, a band which is nearly 1μ broad, and so nearly fills the interval between the lines at α and the next transverse row of dots. There is thus produced an appearance, well shown in the photograph, corresponding to the conventional description of an uncontracted muscle fibre, namely, alternate dim and bright bands, each of the latter being crossed at its middle by a thin dark line. This line is made up of the lines α and the sarcoplasmic accumulations at the same level. It can be inferred with certainty that the muscle columns are constricted at the levels at which the sarcoplasm accumulates, and bulged at the intermediate levels; and by focussing carefully the edge of a fibre, especially if the sarcolemma be displaced, the appearance of four tiny bulges, between each pair of lines α , can be made out. The three constrictions dividing each segment of the muscle columns into four equal parts correspond exactly with those that I have described in the wing muscle sarcostyles, and I shall therefore mark these levels by the same letters $\gamma \beta \gamma$, and fibres showing this appearance are in a state of contraction strictly analogous to that of the wing sarcostyles which I have called stage B.

Photo. 23, taken from a longitudinal section of a fibre fixed by chromic acid in this stage B and stained with logwood, shows in places the lines of separation between the columns marked with slight swellings at the levels $\alpha \gamma \beta \gamma$. These swellings, the accumulations of sarcoplasm, appear much less marked than in photo. 22, partly because the stage of contraction is a very early B stage, partly because the chromic acid causes so much shrinkage, and partly because the lines between the swellings are fairly thick and well stained, being made up, as I believe, of two layers of the stained walls of the columns, which when unstained are scarcely visible.

Parts of muscle columns can be isolated from fibres in this

stage of contraction, almost as easily as from fibres in stage A and by the same methods. Photos. 24 and 25 represent parts of such columns teased out from fibres fixed with chromic acid. In them can be seen the darkly stained α septa with their halos, the longitudinal wrinkles and the three dark transverse lines $\gamma \beta \gamma$ the expression of the transverse grooves in the stained wall at these levels. (These photographs should be compared with those showing the isolated sarcostyles of the wing muscles in the corresponding stages of contraction.) Photo 26 shows muscle column in stage B, isolated after fixation with chromic acid 2 p.c. to which was added 2 p.c. of formic acid. The presence of the formic acid counteracts the tendency to shrinkage caused by the chromic acid, as I shall show below, and longitudinal wrinkles are therefore not present in these columns, but only the transverse lines and grooves. By carefully focussing through the substance of such isolated columns, it is easily made out that their thickness is only about 1μ .

In a fibre of which the parts are unequally contracted, the transition from this stage B to the next well-marked stage C may be traced. The dots of sarcoplasm at the level γ become smaller and those at α and β larger, until, in parts in which the α septa occur at intervals of from $2-3 \mu$ and whose degree of contraction corresponds to stage C of the wing sarcostyle, the dots at γ and γ are no longer seen; or, in other words, the constrictions in the muscle columns at the levels $\gamma \gamma$ become less and less marked until they quite disappear, while the constrictions at the levels α and β become deeper. The dark band at α can still be resolved into the lines α and the diamond-shaped dots of sarcoplasm; the dots of sarcoplasm at β are generally slightly smaller than those at α . Photo. 27, taken from a steamed but unstained fibre, shows very well the distribution of the sarcoplasm. Photo. 28 of a longitudinal section of a fibre fixed with chromic acid and stained with logwood shows the same distribution of the sarcoplasm, but has the peculiarities noted in photo. 23. Photo. 29, which was taken from a longitudinal section of a fibre in stage C stained with gold and cut in paraffin, shows the same thing on a smaller scale. The columns in this stage are a little more than 2μ in thickness. If a spot be found at which the sarcolemma is displaced from the edge of the fibre in

this stage of contraction, it can be clearly seen that the outline is dipped in at the levels α and β , and bulged out between them. Fragments of the lamellar muscle columns may be isolated in this stage of contraction also, though less readily than in stages A and B, and such fragments are crossed by dark lines of two kinds, α and β , which behave to alterations in focus exactly as do the lines α and β in wing sarcostyles at this stage; and if the outer edge be preserved, it can be seen to form a double bulge between α and α ,—i.e., it is drawn in opposite α and β , but less deeply at β (photo. 30). Photo. 26 shows the surface of a muscle column, of which one part is in an early stage, C, and another part in a late B stage.

It will be noticed that in fibres in this stage C of contraction there is nothing which can be described as a dim band, for the halos of the α septa light up the whole length of each segment of the columns.

At a bent part of a contracted fibre it is easy to trace the transition from stage C to more advanced stages of contraction, both along and across the fibre (photo. 34). In passing towards the more contracted parts the dots forming the dark lines at β become smaller, while those at α become larger, until, when the lines α occur at intervals of only $2\ \mu$ or less, the line β is very faintly marked or absent. This stage corresponds exactly with stage D of the wing sarcostyle. There is now a simple alternation of dark and light bands, the latter being rather the broader. The dark band can no longer be easily resolved everywhere into its constituents, the lines α and the sarcoplasmic accumulations (photos 32 and 33). But in places, best perhaps in living or steamed fibres, the outlines of the muscle columns and the distribution of the sarcoplasm can be clearly seen (photo. 31). The segments of the columns appear in optical section, as seen in the longitudinal view of a fibre, as bright areas about $2\ \mu$ or less in depth, and about $3.5\ \mu$ in width, the side walls forming simple semicircular curves between the ends of the dark α septa, just like the optical section of the sarcomeres of the wing fibril in this same stage D. The individual columns can be most clearly distinguished in parts where they have undergone some longitudinal dislocation: this, which is rare in stages B and C, is common in stage A, and

also in this stage D, and is shown in photo. 31. The sarcoplasm is all accumulated at the levels of the α septa, and it is through the optical fusion of these masses of sarcoplasm with the dark α septa that the appearance of a dark transverse band is produced, and it is especially well marked when the sarcoplasm is stained (photo. 32). If the appearance of a fibre in stage D be compared with that of one in stage A or stage B, it will be observed that the phenomenon so often described as the 'reversal of the striation' has been brought about in the contracted fibre.

The appearances described above as characteristic of the various stages of contraction can not only be readily observed in the living fibres (as proved by photos. 19, 22, 27, and 31)—for though these are from steamed fibres, the appearances are exactly the same as in living fibres, as I have already said, and were, in fact, observed in the case of the fibres photographed before the application of steam to the cover-glass—but they comprise all the appearances revealed by an objective of high resolving power, such as the 2 mm. apochromatic of Zeiss, with adequate optical arrangements and accurate focussing. There are, of course, various strange appearances caused when the parts are not accurately focussed, for then the illumination of the light and dark parts is largely reversed. But that the various distributions of the sarcoplasm that I have described in the living fibres are real, and not due to optical illusions of any kind, is proved by preparations with various chemical reagents and stains. Chromic acid .2 p.c. usually fixes the parts with absolute accuracy as far as the longitudinal view of the fibres is concerned; and the sarcoplasm may then be stained with logwood, and its distribution observed in longitudinal sections. Staining by immersion of the living fibres in gold chloride, without previous immersion in acid, gives rather uncertain results, because the formic acid used for reduction of the gold salts exerts a powerful deforming action on the muscle columns. Yet in thin sections cut from muscle prepared in this way and embedded in paraffin, there may be found parts in which the normal distribution of the sarcoplasm, characteristic of all stages, is retained. The pictures yielded by such parts are sometimes beautifully clear (though on a very small scale, owing to the shrinkage

caused by dehydration) (see photo. 29), and are valuable as corroborating the truth of the descriptions of the living muscle fibres in which the optical conditions are so much more complex.

The appearances presented by transverse sections of the muscle fibres are in accordance with those of longitudinal sections or surface views. Transverse sections may be cut from the living fibres by freezing them in white of egg, as recommended by Rollett. Or good sections may be cut with the freezing microtome from fibres fixed by steam or formaline, and stained on the slide with logwood. In sections so prepared, the lines of sarcoplasm run out radially from the central core to the periphery without any breaks, and the narrow radial un-

Fig. 13.—Diagram of part of a fibre, showing stages A, B, C, D in neighbouring parts.

stained sections of the muscle columns also run from core to periphery without any break or interruption. In sections of extended fibres the lines of sarcoplasm can be focussed down through the thickness of the section without variations in width, and the sections of the muscle columns are uniformly about 1.3 to 1.5 μ in width. In sections of fibres in other stages the lines of sarcoplasm vary in width with alteration of the focus; and in sections of well contracted fibres it can be made out that, as the focus is carried downwards through the section, the lines of sarcoplasm undergo a regular variation, being very narrow at some levels corresponding to the bulged middles of the segments of the columns, and being much broader at levels alternating with these, and about 1 μ or less different in depth of focus. If the focus be varied very carefully about this latter level a point is

found in well-stained sections at which the bright areas, the sections of the muscle columns, appear stained also, so that the field appears stained almost evenly in this part. This last appearance is, of course, due to the focus being accurately at the plane of the darkly-stained α septa. Photo. 35 shows at the parts marked in the key the appearances of all these three foci. In other parts a fine dark line, occasionally two lines, can be seen running through the bright area parallel to their long sides; and as the focus is varied, this line passes rapidly across the area. It is therefore probably the optical section of a transverse septum in the muscle column, lying slightly obliquely to the plane of the focus.

DESCRIPTION OF THE PHOTOGRAPHS.

The photographs were taken with the 2 mm. apochromatic homogeneous immersion objective of Zeiss, with projection ocular and achromatic sub-stage condenser. The source of light was the oxyhydrogen lime-light in all except a few cases, in which the electric arc lamp was used. The magnification, except in the few cases where the magnification is given below the photographs, was a little more than 1000 diameters. To see all the details given in the photographs, it is necessary to examine them closely in a good light, preferably daylight. The parts which were accurately focussed, and to which I wish to draw attention, are indicated in the key to each photograph by a slight filling in of the outline sketch. It should be remembered that the 2 mm. apochromatic focusses very accurately in one plane only. Some of the photographs have suffered an unavoidable loss of definition in the processes of reproduction.

(To be continued.)

**A RARE CONDITION OF THE VERMIFORM APPEN-
DIX.** By A. FRANCIS DIXON, M.B., *Chief Demonstrator of
Anatomy, Trinity College, Dublin.*

A MALE subject, aged 50, dissected in the Anatomical Department of Trinity College, Dublin, presented what must be considered to be a very rare condition of vermiform appendix. This process was not only of unusual length, but lay, except at its very commencement and termination, on the posterior abdominal wall behind the peritoneum. Its direction was vertically upwards behind the ascending colon. On raising the ascending colon, and drawing it towards the middle line, there was found to be a distinct ascending mesocolon, which was attached to the posterior abdominal wall along a vertical line extending from a point 2 cm. beyond the bifurcation of the common iliac artery, upwards towards the region of the second part of the duodenum. The elongate vermiform appendix lay close beside the right side of the root of this mesentery, except near its distal end, where it was turned a little towards the right, and away from the root of the mesocolon. The blind end of the appendix, which was somewhat bulbous, reached just to the level of the under surface of the liver.

In length the appendix was exactly 16·0 cm., and it was easily demonstrated to be pervious throughout its entire extent by inflating the cæcum with air. Only the terminal part, which was about 1·0 cm. long, was completely invested by the peritoneal membrane; the rest, as already stated, lay behind the peritoneum, and was only partly covered by it.

Just at the point where the free portion joined the fixed part a small but sharply defined fold of peritoneum passed upwards towards the under surface of the liver. This fold, which appeared to enclose a feeble fibrous band or cord, was found to end above at a place where the peritoneum, covering the under surface of the liver, was adherent over a small area to that on the anterior surface of the kidney. The diameter of this area was about 1·0 cm. The direction of the peritoneal fold did not

accurately correspond with the long axis of the appendix, but was more oblique, as is seen in the drawing. The bulbous portion of the vermiform process might be said to begin just above the attachment of the fold.

In seeking an explanation for this curious arrangement of the vermiform appendix, we obtain in this peritoneal fold the key to the explanation of the conditions present. It would appear that, for some reason, localised peritonitis in utero caused an adhesion of the peritoneum covering the kidney with that over the liver. At a time when the cæcum was undescended the vermiform process lay close to this region of inflammation, although it was probably not actually involved in it, even superficially. It seems further necessary to assume that even at this early period, contrary to what is usually found, the greater part of the appendix lay behind the peritoneal cavity. If this were so, the point where the appendix came forward through the peritoneum to lie in the abdominal cavity would be well fixed. In the course of development, as the cæcum descended towards the iliac fossa, that portion of the peritoneum, which lay over the area, between the region of inflammatory adhesion and the place where the appendix became completely surrounded, was stretched into the ligamentous fold seen in the adult. At the same time the proximal portion of the appendix, lying between the cæcum and most fixed part of the vermiform process, was drawn out more and more until it assumed the elongated form found in the adult. The distal part of the appendix lying above the fixed portion, and completely surrounded by peritoneum, was not subjected to this strain due to the descent of the cæcum, and so is found to have a bulbous appearance in the adult.

The somewhat peculiar form of cæcum present is compatible with this tension theory for the elongated vermiform process seen in this subject. The cæcum is very sharply bent upon itself; and its true apex, where the three longitudinal muscular bands come together, is directed vertically upwards behind the rest of the colon, and lies a little above the level of the ilio-cæcal opening.

With regard to the length of the appendix, which we have already stated was 16·0 cm., we note that Treves,¹ from an

¹ "Anatomy of Intestinal Canal and Peritoneum in Man," *Hunterian Lectures*, 1885.

examination of 100 cases, gives the extremes in length as being 1 inch and 6 inches (15·2 cm.). Berry,¹ in a similar number of cases, found the appendix in two specimens 13·3 cm. in length,

Drawing to illustrate a rare condition of the Vermiform Appendix. The cecum and ascending colon have been raised and turned towards the right, and the elongate appendix is seen passing upwards towards the liver. From a point just below the somewhat bulbous terminal part of the vermiform process a fold of peritoneum is seen passing upwards towards the under surface of the liver, and behind the gall-bladder. To the left of the appendix is the ascending mesocolon.

¹ "The Anatomy of the Vermiform Appendix," *Anatomischer Anzeiger*, Band x., 1895, p. 762.

and he refers to a specimen 19 cm. long recorded by Ransohoff, and another 23 c.m. in length. From the number of observations which have been recorded on the length of the appendix we may safely say that only very rarely does it exceed 15.0 cm. in length.

Perhaps the most remarkable fact noticed with regard to the vermiform process in this subject was its relation to the peritoneum. The variations in the normal arrangement of the peritoneum in connection with the appendix have received careful attention from Treves and Berry. The former considers that in some cases the appendix loses its mesentery, and becomes enclosed in the same fold as the cæcum. The latter, however, is of opinion that "the appendix is always entirely surrounded by peritoneum, and that it always has a mesentery: any possible exception is probably pathological, and in any case extremely rare."¹ As mentioned above, it seems probable that even at a very early stage in the development of this subject, the greater part of the appendix lay behind the peritoneum, just as it did in the adult.

Lastly, with regard to the position of the appendix, Treves states that in 18 per cent. of his cases the process passed vertically upwards behind the cæcum. In four the tip of the process came near to, if not into actual contact with, the under surface of the liver. He does not state whether in these cases the appendix lay to the left, or, as in this subject, to the right of the ascending colon or its mesentery.

¹ *Ibid.*, p. 767.

CASE OF COMPLETE TRANSPOSITION OF VISCERA. By
RICHARD CATON, M.D., F.R.C.P., *Physician, Liverpool Royal
Infirmary.*

W. B., aged 36, brewery labourer, was admitted to one of my wards on 12th December 1896, suffering from acute rheumatism, mitral disease, albuminuria, and delirium tremens.

On examining the thorax anteriorly, no dulness was found on the left side above the sixth rib, and only feeble and distant cardiac sounds were audible on auscultation. On the right side a roughly triangular area of dulness was found, bounded below by the sixth rib, and extending in the fifth space two and a half inches to the right of the sternum; its superior angle rising to the fourth cartilage. The apical cardiac impulse was felt about two and a half inches from the middle line on the right. The cardiac sounds were heard here distinctly, also a systolic bruit, audible some distance into the right axilla. An accentuated second sound heard at the lower end of the sternum was supposed to arise from the pulmonary valve. On examining the abdomen, no hepatic dulness was found on the right side; but on the left, below the sixth rib, an extensive dull area stretched from the ensiform cartilage to the axilla.

The patient is left-handed.

The case terminated fatally on the 17th December. Autopsy on the 18th.

The *brain* was normal, but the convolutions of the Rolandic area were remarkably complex on the right side. The longitudinal sinus joined the left lateral sinus.

On opening the *thorax*, the apex of the heart was found lying about four inches to right of the middle line. A short right aortic arch, passing directly back to the right of the spinal column, was found continued downwards in that relation to the column. A left innominate artery, and right common carotid and subclavian. Ductus arteriosus well marked, not patent. The front part of the heart consisted of right auricle and ventricle, a small portion of the left, or systemic, ventricle being visible on the right. The left lung consisted of three lobes, the right of two, the bronchi being transposed. The right bronchus passed under the arch of the aorta.

On opening the *abdomen*, the liver was seen lying on the left, and the stomach protruding to the right, the pylorus being transposed. The spleen was on the right, forming one mass, instead of being in several detached and scattered portions as in most cases of transposition. The horse-shoe curve of the duodenum and the pancreas were transposed, as also were the sigmoid flexure, cæcum, and rectum. The left kidney was lower than the right, and the right testis lower than the left. I have to thank Professor Boyce, Dr E. A. Smith, medical tutor, Dr Gullan, my house-physician, and Mr G. G. Lawson, clinical clerk, for aid in recording this case.

✓ ON THE REGENERATION OF NERVES. By ROBERT KENNEDY, ✓
M.A., B.Sc., M.D. Glasgow. (Communicated by Professor
M'KENDRICK, F.R.S., to the Royal Society of London, and read
February 11, 1897.)

(*Abstract.*)

The author treats the subject under the following heads :—

I. A short historical and critical review of the books and papers which have appeared on the subject from the time of Cruikshank (1776).

II. Clinical reports of four cases of secondary suture of nerves as follows :—

1. Suture of the median and ulnar nerves six and a half months after division in the middle of the forearm. There was total loss of sensation and motion in the distribution in the hand, and marked atrophic changes. Three days after the operation, sensation commenced to return; by the nineteenth day touch was correctly localised on all parts of the fingers; and by the end of the first month, sensation was almost perfect. Improvement in motion was slow and imperfect.

2. Suture of the median three months after complete division above the wrist. Sensation was lost in the median distribution, and opposition of the thumb was impossible. There was marked atrophy of the thenar eminence. Two days after the operation, sensation commenced to return. Both sensation and motion speedily improved, and by the end of a year recovery was almost perfect.

3. A case in which the median, musculo-spiral and ulnar were involved in cicatricial tissue at the seat of fracture at the elbow joint; excision of portions from median and musculo-spiral, and suture two months after accident. There was total anaesthesia in the distribution of the affected nerves, and paralysis of the muscles. Sensation, after the operation, commenced to return on the fourth morning, but made slow progress. The case was under observation for six weeks only, at which time no improvement had occurred in motion, but sensation was present in the fingers.

4. Suture of the ulnar nerve eighteen months after division. Sense of pain was totally lost in the ulnar distribution. Five days after the operation, sense of pain returned in the little finger, and by six weeks sensation was almost perfect, although motion had not improved.

III. Deductions from the results of operation.

From the above results the author concludes that the early return of sensation must be regarded as indicating a restored conductivity of the divided nerve. He holds that the theories which have hitherto been advanced to account for early return of sensation apart from reunion of the nerve, are inapplicable to cases where *early* return of sensation occurs from suture, performed after the lapse of *several months* from the time of section. The imperfect return of motion he takes to be fully explained by the fact that the muscles have undergone great trophic change, or indeed total destruction, and that, therefore, their restitution must be slow, or may even be impossible.

IV. Microscopical examination of the portions removed previous to suture.

Both the central and peripheral ends of nerves which had not reunited in any way, contained young nerve fibres grouped in bundles, each bundle containing, as a rule, many fibres. The fibres contained an axis-cylinder lying in the centre of a clear, well-defined zone, which, again, contained a granular, myeline deposit, while spindle-shaped nuclei were attached to the sides of the fibres at frequent intervals. Where the ends of the nerve were united by a cicatricial segment without conductivity being restored, the examination of the segment showed a dense network of connective tissue, containing in its meshes bundles of young fibres.

The portions excised from the nerves involved at the seat of fracture showed at their central ends a normal structure, but elsewhere no trace of old myeline fibres, nor of degenerated fibres; but the section was made up of young fibres in bundles, which bundles were of only slightly greater diameter than the old myeline fibres, and often surrounded by a delicate sheath. At the point of transition from old to young fibres, many of the old myeline fibres contained an enlarged nucleus, with one or two distinct young fibres lodged between the sheath of Schwann and the myeline sheath. In other cases the number of young fibres lying in a similar position was greater. All stages up to complete replacement of the old myeline sheath and axis-cylinder by young fibres were found.

V. Deductions from the microscopical examination.

1. Degeneration.—

(a) That there is no evidence of ascending degeneration of the kind described by Krause after interruption of a nerve.

(b) That the old axis-cylinder and myeline sheath are destroyed in the peripheral segment, and in the ultimate portion of the central segment.

2. Regeneration.—

(a) That young nerve fibres are developed in the peripheral seg-

ment, as well as in the end of the central segment, and that even while there is no connection between the two ends.

(b) That these young nerve fibres originate within the old sheath of Schwann from the protoplasm and nucleus of the interannular segment. The spindle-cells formed from the protoplasm and nuclei of the interannular segments elongate and unite to form protoplasmic threads, with the elongated nuclei attached to their sides. The central portion of the protoplasmic thread develops into the axis-cylinder, while myeline is deposited in drops in the protoplasm surrounding the newly formed axis-cylinder. The protoplasm in which the myeline is deposited remains with the nucleus as the neuroblast of the new interannular segment.

(c) That so long as conductivity of the nerve is not re-established, the development of the fibres proceeds only to a certain stage ; and as the new fibres three months and eighteen months subsequent to division present identical characters, this stage may be regarded as a resting stage, depending for its further development on re-establishment of function.

(d) That cicatricial intercalary segments reuniting the ends of a divided nerve may be permeated by young fibres from end to end without re-establishment of function, if the amount of cicatricial connective tissue present in the mass is sufficient by its pressure to prevent the passage of impulses. /

SEVENTH REPORT ON RECENT TERATOLOGICAL LITERATURE. By **BERTRAM C. A. WINDLE**, D.Sc., M.D., M.A.,
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[The author of this report will feel greatly obliged if writers on teratological subjects will supply him with reprints of their communications, for use in the preparation of future reports.]

I. CLASSIFICATION.

THE subject of teratological classification is at present in so chaotic a condition that one welcomes any effort to reduce it to order, and two papers with this end in view have recently appeared. The first of these by BLANC (i.) commences by giving an account of the various schemes of classification which have been proposed up to the present date. The defects of each are indicated, and reasons given to account for the extreme difficulty which besets the task of compiling a classification of the kind. It may here be remarked that the author does not appear to have met with the classification proposed by Professor Cleland some years ago, in *Memoirs and Memoranda on Anatomy*. In constructing his own scheme, the author starts with the axiom that abnormal forms, even more than zoological species, are united to one another by insensible links, binding together the chain which commences with the normal form and terminates with the most extreme form of abnormality. He considers that the linear form of classification is inadequate, and that the better form of grouping resembles a genealogical tree, divided by a dichotomous process. The trunk, whether single or double, represents one or several parallel series leading to the maximum of the malformation, and the branches are the secondary deviations which modify one or other type of the series. This method he thinks is particularly applicable to the classification of double monstrosities, and in dealing with this class he includes therein all forms in which the subject contains double organs forming part of a series which leads up to obvious double monstrosity: thus a duplicity of the bucco-nasal region is for him a double monstrosity. Further, he bases his classification on the point which he, in common with the distinguished French teratologist, M. Camille Dareste, but in opposition to most other teratologists, considers to be undoubted, viz., that all double monstrosities arise in a single ovum with two nuclei; that is, that all duplicity is original, and that the various forms thereof are produced by a greater or lesser amount of subsequent fusion. M. Blanc is prepared to push this view to its logical conclusion, for he points out that the form of the double monster is determined by the epoch at which the two nuclei or their products come into contact, which may be (a) after the two embryos have made considerable progress in development; (b) when they are commencing

development; (c) before the embryo has appeared. In the last-mentioned case there is always more or less atrophy of the halves in contact, and this process of regression may lead to the almost total disappearance of one of the embryos. Thus he postulates the original potentiality of complete duplicity even in such forms as diphallus, dirhinus, and dignathus. The scheme of his classification, without details, is as follows:—

| | | | |
|--|---|----------|---|
| Abnormal forms proceeding from an ovum with nucleus . . . | { | multiple | ..Triple or quadruple monsters. |
| | | double | { Double monsters. |
| | | single | { Homologous twins, well or ill formed. |
| | | ... | Abnormal individuals (Monstres uni- taires). |

In dealing with the last of the divisions, it is, he thinks, impossible to use any classification based on the physiological, anatomical, or æsthetic gravity of the condition. The classification must be formed by dealing with each organ or system separately, and under the following heads:—

| | |
|-----------------------------------|-----------|
| Anomalies of Growth, | { Defect. |
| | { Excess. |
| Anomalies of Formation, | { Defect. |
| | { Excess. |
| | { Vice. |
| Anomalies of Evolution, | { Defect. |
| | { Excess. |
| | { Vice. |
| Lesions and Diseases. | |

TARUFFI (ii.), after a critical examination of some of the schemes of classification at present more or less in use, gives the following arrangement for double forms, which is here given *in extenso*, in the hope that it may be of service to teratologists working at this difficult subject:—

Twins contained in a single chorion (Terata Polisomata).

Group I. The twins are separate from one another.

Fam. 1. True twins (Homologe Zwillinge, Ahlfeld; Disomi monocori, Taruffi).

Fam. 2. Twins whose umbilical vessels anastomose. One twin wants head and heart, or possesses some defective part (Acephali, Mappo Marco, 1687; Allantois-parasiten, Ahlfeld; Disomi omphalopaghi, Taruffi).

Gen. α . One twin has head and heart defective (Paracephalus, I. G. St Hilaire).

Sp. 1. One twin has defective head and no arms (P. dipus, Taruffi).

Var. α . The defective twin has a heart (P. dipus cardiacus, Taruffi).

Var. β . The defective twin has no heart (Cefalo-acardiacus, Calori; P. dipus acardiacus, Taruffi).

Sp. 2. One twin has defective head, and neither heart nor limbs (Heteroide, Pictet; P. apus, Taruffi).

- Sp. 3. One twin has imperfect head and rudimentary trunk (Acormus, Förster; *P. pseudo-acormus*, Taruffi).
- Gen. *b*. One twin is destitute of a head (Acephalus, Brescet).
- Sp. 1. This twin has thorax and limbs (*A. thorus*, Taruffi).
- Var. *a*. Has thorax and heart (*A. thorus cardiacus*, Taruffi).
- Var. *β*. Has thorax, but no heart (*A. thorus acardiacus*, Taruffi).
- Sp. 2. The twin without head or thorax has lower extremities (*A. athorus*, Brescet).
- Sp. 3. The twin has only pelvis and lower extremities (*A. gastrus*, Brescet; *A. pseudo-acormus*, Taruffi).
- Gen. *c*. One twin possesses no approach to the normal form (*Amorphus*, Gurlt).
- Sp. 1. Has a globose form, with rudimentary limbs (*Mylacephalus*, L. G. St Hilaire).
- Sp. 2. Has a globose form, without any limb rudiments (*Anideus*, L. G. St Hilaire).

Group II. Twins with united bodies (*Disomi sineriti*, Taruffi).

Ord. A. Twins symmetrically united (*D. simmetrici*, Taruffi).

Fam. 1. United principally by the head (*Sycephalus*, I. G. St H.; *Syncephalus*, Förster, Taruffi).

Gen. *a*. United only by the head (*Craniopagus*, Förster, Taruffi).

Sp. 1. Union by sinciputs (*Acrocephalus pagus*, Taruffi).

Sp. 2. Union by occiputs (*Iniopagus*, Taruffi).

Sp. 3. Union by foreheads (*Metopagus*, Taruffi).

Gen. *b*. United by head and thorax (*S. torocopagus*, Taruffi).

Sp. 1. The two faces are laterally united, and turned more or less to the abdominal side. The two trunks are united as low as the umbilicus (*Hemipagus*, I. G. St H.; *Octopus symphiocephalus*, Gurlt; *S. diprosopus monopediis*, Taruffi).

Var. *a*. Four eyes (*S. diprosopus tetrophthalmus*, Taruffi).

Var. *β*. Three eyes (*S. diprosopus trioftalmus*, Taruffi).

Var. *γ*. Two eyes, but obvious evidence of two heads (*S. diprosopus dioftalmus*, Taruffi).

Sp. 2. The two faces are opposite and symmetrical (*Jani-ceps*, Zshokke; *J. symmetros*, Förster; *J. teleus*, Taruffi).

Sp. 3. One of the two opposed faces is imperfect (*Octopus*, Gurlt; *J. asymmetros*, Förster; *J. ateleus*, Taruffi).

Var. *a*. The imperfect face has only a median eye (*J. cyclopus*, Taruffi).

Var. *β*. The imperfect face only possesses rudiments of two approximated ears (*J. synotus*, Taruffi).

Sp. 4. Twins with one head and face and two trunks (*Octopus biauritus*, Gurlt; *Monocephalus*, I. G. St H.; *Synceph. monoprosopus*, Taruffi).

Gen. *c*. Twins with head and thorax single, and two more or

less complete pelves. (The vertebral column is doubled posteriorly.) (Ileadelpus, I. G. St H.; Synceph. dilecanus, Taruffi.)

Sp. 1. Two pelves attached laterally to the vertebral column, with indications of posterior duplicity (Dilecanus dipleurus, Taruffi).

Var. α . Two pelves so far apart as to allow of four limbs. Sacrum single, but with indications of duplicity (D. dipleurus, Taruffi).

Var. β . Two pelves represented only by the external ilium of each. Hypothetical variety in cases of double penis or vulva (D. dipleurus dipus, Taruffi).

Sp. 2. The ilia of one pelvis are united by the divaricated pubes with those of the other, so as to form one large cavity, on the opposite sides of which lie the two sacra (D. ibipagus, Taruffi).

Var. α . Each pelvis has its ilia and acetabula complete (D. ibipagus tetrapus, Taruffi).

Var. β . Each pelvis has only its external ilia complete; the internal are incomplete, and bear a single acetabulum (D. ibipagus tripus, Taruffi).

Fam. 2. Twins united principally by the pelves (Dicephalus, Haller; Lecano-pagus, Taruffi).

Gen. α . Possessing all the usual limbs (L.-p. tetrabrachius et tetrapus, Taruffi).

Sp. 1. United by ossa innominata, so that a single pelvic cavity is formed (Ischiopagus, I. G. St H.).

Var. α . Disposed around one median axis (I. dichordus eutygrammus, Taruffi).

Var. β . Axes converge inferiorly (I. dichordus catagoniodes, Taruffi).

Sp. 2. United by region of nates (Pygopagus, I. G. St H.).

Gen. β . Twins united by pelvis and thorax, or directly by the vertebral columns (Sterno-pelvididymia, Cruveilhier; Lecano-somato-pagus, Taruffi).

Sp. 1. United by pelves and thoraces, axes parallel, four upper and lower limbs (Somatopagus parallelus, Taruffi).

Sp. 2. United by pelves and thoraces, three lower exts. (Ischiodymia trimeliana, Serres; Dicephalus tripus, Förster; Somato-catagonioides tripus, Taruffi).

Var. α . Three lowers and four uppers (S.-c. tripus tetrabrachius, Taruffi).

Var. β . Three lowers and three uppers (S.-c. tripus tribrachius, Taruffi).

Sp. 3. United by pelves and thoraces, with two lower extremities (S.-c. dipus, Taruffi).

Var. α . Dicephalus tetrabrachius, Förster; Dipus tetrabrachius, Taruffi.

Var. β . *Dicephalus tribrachius*, Förster; *Dipustribrachius*, Taruffi.

Var. γ . *Derodimus*, I. G. St. H.; *Dipus dibrachius*, Taruffi.

Gen. *c*. United by pelves and thoraces, and having two heads united laterally (*Monosomus*, I. G. St. H.; *Lecanopagus diprosopus*, Taruffi).

Sp. 1. One body with two heads laterally united, and converging so as to form an angle with its apex below. Each face has two orbits (*Iniodymus*, I. G. St. H.; *Diprosopus tetrophthalmus*, Taruffi).

Sp. 2. One body with two heads joined laterally, and converging to form an angle with its apex above, so that there is only room for three orbits (*Diprosopus triophthalmus*, Taruffi).

Sp. 3. One body with a single head rather larger than usual, with two eyes, two noses, and one or two mouths (*Diprosopus diophthalmus*, Taruffi).

Fam. 3. Twins united by epigastria or thoraces (*Thoracopagus*, Förster).

Gen. *a*. Union by epigastria and xiphoid cartilages (*Xiphopagus*, I. G. St. H.).

Gen. *b*. Union by epigastria and separated sterna (*Sternopagus*, I. G. St. H.).

Sp. 1. Each has two arms (*S. tetrabrachius*, Taruffi).

Sp. 2. The twins are rotated somewhat externally and possess three arms, one of which is median and posterior (*Ectopagus*, I. G. St. H.; *S. tribrachius*, Taruffi).

Sp. 3. Still further rotated externally, and possessing each only one arm (*S. dibrachius*, Taruffi).

II. EXPERIMENTAL.

KÄSTNER (iii.) gives an account of a series of experiments on hens' eggs, during the incubation of which the artificial heat was cut off for a longer or shorter time, and the eggs allowed to rest at the temperature of the room in which the apparatus stood. In a further paper (iv.) he gives more fully the results of these experiments. If the unbroken temperature does not fall more than 7° C. under 28° C., the maximum period for which the artificial heat can be cut off is at the commencement of the earliest stages of development 3 weeks, at the end of the same 6 days, at the 6th day 72 hours, at the 9th day 48 hours, in the second half of development up to its termination 24 hours. He thinks that the injury to the embryo is due to mechanical causes, the cooling of the yellow yolk causing the embryo to be pressed against the vitelline membrane, to which it partly adheres. This explains why such injuries occur in the early stages when the embryo is unprotected by the amnion and in the horizontal position, but not in

the vertical, since in the latter it is saved by the air-space. Numerous varieties of malformations were met with, such as deficient formation of the blood-islands in the area vasculosa, total atrophy of the embryo, hydrops, arrest of development of the head, heart, and anterior amniotic folds, with the formation of various abnormal clefts. O. HERTWIG (v.) alludes to the fact that he and Morgan have shown that frog-ova hatched in a .6 per cent. solution of salt gastrulated abnormally. In the experiments detailed in the present paper, the ova of *Siredon pisciformis* were hatched in solutions varying in strength from .5 to .8 per cent. In many ways the results obtained agreed with the observations made upon the frog-ova, but there were some marked differences. The gastrulation process was much interfered with in the case of the frog, but not in that of the axolotl, perhaps because the ova were placed in the solution at a later stage of development. Again, in the frog, as a rule, only the cerebral part of the neural tube is affected, whilst in the axolotl all parts save that lying in the tail suffered. The effect was most commonly exerted on the last three brain segments, the anterior pair being sometimes quite or nearly closed. In all cases the optic and otic vesicles were formed. In higher grades of injury, the failure to close extended as far as the tail. In the axolotl, the development of the rest of the body excepting the nervous system was practically normal; in the frog, as the result of the defective gastrulation, there were many other disturbances of development. Small changes in the strength of the solution made a great difference in the results: thus .5 per cent. had little effect, .6 per cent. considerable, and .7 per cent. one still greater. The author points out that, in a former communication (*Report* iii., this *Journal*, vol. xxvii.), he has called attention to the relation between known human abnormalities and those artificially obtained in amphibians, and thinks that the results now given may point to the fact that a poison of some sort, such as alcohol or a toxin circulating in the mother's blood-vessels, may produce malformations in the embryo. WETZEL (vi.) has used Schultze's method with frog-ova (described in *Arch. f. Entwicklungsmech*, Bd. i. hft. 2), which consists in placing the ovum, with the white pole downwards, between two glass plates, which exert firm pressure upon it, and then, during the formation of the first line of segmentation, twisting it round, so that the white pole comes uppermost. The glass plate must be quite horizontal, and the axis of the ovum exactly vertical. According to Schultze, all forms of double monstrosities are produced from eggs so dealt with. In some cases Wetzel found no duplicity, but he describes double monsters united side by side, and also one case of triplicity obtained by this method. The paper contains figures of some of these monsters, and of sections through them at the third day of their development. CHARRIN (vii.) having injected various toxins (mallein, tuberculin, etc.), and subsequently a culture of pyocyanic bacillus, into pregnant cavies and rabbits, with a view of ascertaining whether they would pass into the embryo, found that inoculations made from the foetuses, after aseptic removal, produced cultures, but not in the cases of those taken from control animals. Where the foetuses were allowed to develop, malformations, such as partial atrophy of the ears, torsions

of the bones (especially the tibia and femur), and arrest of development of the limbs, with absence of the foot, were observed. FÉRE (viii.) finds that the introduction into the eggs of hens, prior to incubation, of snake-venom, also the exposure of eggs whilst incubating to the emanations of musk and the vapours of essences such as oil of thyme or of wintergreen, produce a large number of malformations. The same worker (ix.), experimenting with acetone, found that its introduction in dilute doses produced scarcely any teratogenic effects. The same worker (x.) experimented with eggs into which small quantities of rum and other spirits and of various kinds of wine were introduced, all of which exerted teratogenic effects. It is interesting to note that both red and white wine were more injurious than an equivalent dose of pure alcohol, showing that, with them, the alcohol was not the only disturbing agent. This may be compared with Daremburg's observation, that a rabbit which will resist a diluted dose of alcohol equal to the amount contained in a given quantity of wine, will not resist that amount of wine.

III. GENERAL

GIACOMINI (xi.) in this paper gives a resumé of the work which has recently been done, largely by himself, on *early malformed foetuses*, since attention was first called to them by His. These observations have already been described in previous reports, and in a paper by the present reporter, on "Early Malformations of the Embryo," in this *Journal*; whilst in last year's report will be found Giacomini's classification of these forms. NAGEL (xii.) describes a *dwarf* known as Princess Paulina, who at the time of her death was 19 years of age, and measured 19 inches in height. She was perfectly developed in every way, and very intelligent, speaking four languages. At birth she measured 12 inches. FÉRE (xiii.) gives an interesting table of the *teratological stigmata* in the cases of 194 deaf-mutes, the condition being sometimes congenital, sometimes acquired. The congenital present a greater number of stigmata, and are generally less intelligent; and the less intelligent they are, the more stigmata they present. APERT (xiv.) describes a case of the kind known as *Phocomelia*, under the name of *Achondroplasia*. This condition has also been spoken of as intra-uterine rachitis, but incorrectly. The dimensions of the head and trunk are normal, but the limbs are shortened, and the bones exhibit angular bendings, not rounded as in rickets. CLAUS (xv.) describes a case of *Monopodia*: the thigh contained a femur with an enlarged lower epiphysis, and the foot was reduced to a single toe. Kidneys, ureters, bladder, anus, and external genitalia were wanting; and, as usual, there was only one umbilical artery. BERTACCHINI (xvi.) gives a full account of the anatomy of the *head of a cyclops*, with two eyes included in the orbit.

IV. DUPLICITY.

SECQUES (xvii.) describes two double fish: (a) *Salmo lacustris*, twins attached venter to venter, one being slightly smaller, and having a

malformed tail ; (b) *Trutta fario*, twins of equal size, also attached venter to venter. VALENTI and PISENTI (xviii.) describe an interesting case of *duplicitas parasitica*, the attached twin being represented externally by the two lower limbs and penis, which were appended to the lower part of the anterior abdominal wall of the autosite, which was, of course, also male, and provided with external genitalia. The pelvis of the parasite was composed exclusively of the two iliac bones ; the bones and muscles of its two lower extremities were normal, save for fatty degeneration of the latter. The right lung had four lobes, and the liver had a deep sulcus on its right lobe ; there were two splenuli. The small intestine divided into two parts about 20 cm. above the ileo-cæcal valve, and each of these portions was connected with a large intestine ; that of the autosite terminating normally, but that of the parasite ending in a blind sac, which was much distended by fæcal matter. The circulatory system presented interesting abnormalities. From the right ventricle, which was very large, originated two vessels, that of the right side giving off an innominate, and the left carotid and subclavian, and terminating by a narrow passage in that of the left, which, before forming an arch, like that of the aorta, gave off the two pulmonary arteries. At the undefended spot of Peacock, there was a small orifice by which the two ventricles communicated with one another. The arch formed by the small passage and the left vessel were evidently formed by the fifth left arch (as in two cases hereafter to be mentioned, xxvii. and xxviii.), and the condition was accompanied by a transposition of the aorta and pulmonary artery. GÜNSBURG (in a paper translated by Ballantyne) describes (xix.) a case of the *abortion of four foetuses* at the 4th month of pregnancy : three of these were males and one was a female ; and there were two placentæ, one of which was compounded of three. One of the male foetuses was a *paracephalus* ; its head resembled a fleshy malformed mass, broad at its upper and narrow in its lower part. In the cranium the occipital bone was absent ; the frontal bones were also abnormal, for their facial parts were wanted. The eyes, mouth, and ears were absent, but the nose was normal. In the middle part of the face, and from prominences corresponding to the zygomatic bones, two muscular masses passed downwards, and ended by converging in the region of the clavicles. Similar muscular masses passed from the posterior part of the head on to the back. The sternum was absent. In its place was a thin membrane, under which could be seen the organs of the thoracic cavity. The upper limbs were deformed. The forearm ended in three eminences, resembling fingers. The abdomen showed a fissure, through which a portion of the intestines was prolapsed. The genital organs (male), consisting of a penis and scrotum, were normal. Dr BALLANTYNE considers that this is a unique case of the occurrence of a *paracephalus* as one of quadruplets.

V. HEAD AND NECK.

VALENTI (xx.) describes a brain in which the *two optic thalami were united* by their mesial surfaces, the part in common measuring from

its superficial aspect 14 mm. in length and 8 mm. in depth. A microscopic examination showed that the structure of one thalamus passed into the other without any trace of demarcation. Through the section were scattered small fusiform or irregularly polyhedral cells, with multiple prolongations. MORISON (xxi.) describes a *tumour of the orbit* in a new-born child, which bore two tubercles, one of which had cut an incisor tooth, and the other was about to do so. It was removed, and was found to block the upper part of the nose and to have a solid base. It was about the size of a Tangerine orange; and when examined microscopically by Targett, who considers it to be an Epignathus, was found to consist chiefly of fibrous and mucous tissue. Ballantyne says that it may be regarded as a teratoma, an exoprosopus amorphus, or as an accessory upper jaw.

FRICCIUS (xxxii.) gives an account, chiefly of surgical interest, of the cases of *hare-lip* observed at Kiel from 1875 to 1895. The following statistics, drawn partly from his records and partly from the literature of the subject, are of teratological interest. It was met with in 550 cases (62·5 per cent.) in males, and in 330 cases (37·5 per cent.) in females; on the left side in 447 instances (52 per cent.), on the right in 183 (21 per cent.), and on both sides in 232 (27 per cent.). It was uncomplicated in 224 (35·2 per cent.), and complicated by alveolar or palatine cleft in 412 (64·8 per cent.). From these figures it follows that hare-lip is more common amongst males than females, on the left side than on the right, as a complicated condition than as a simple one. The influence of heredity was traceable in 53 out of 547 cases, *i.e.*, 11·5 per cent.

FAHRENBACH deals also with *hare-lip* in relation to cases met with at Göttingen (xxiii.) during the ten years since Stobwasser's paper (included in Friccius' thesis) appeared. This paper is also chiefly of surgical interest. The cases observed numbered 200, and of these 143 (68 per cent.) occurred in males, 67 (32 per cent.) in females. They were distributed as follows:—

| | Male. | Female. | Total. |
|-------------------------------------|-------|---------|--------|
| One-sided, simple, | 26 | 15 | 41 |
| „ complicated with cleft, | 80 | 31 | 111 |
| Both sides, simple, | 3 | 5 | 8 |
| „ complicated, | 35 | 16 | 51 |

Amongst the one-sided cases, 112 were of the left side and 40 of the right. Thus these figures tell the same tale as those of the preceding paper. The influence of heredity was traceable in 5·5 per cent. of the cases, and in many instances there were other accompanying malformations.

WINCKEL (xxiv.) discusses the condition known as *agnathia*, which he believes does not really merit this name, since there are, he thinks, always rudiments at least of the apparently absent lower jaw, in some cases adherent to the base of the skull. The paper details

several cases in support of this contention. BALLOWITZ (xxv.) describes a Javanese skull in which there was a *supernumerary incisor* in the left premaxilla imbedded in the bone, with the apex of its root pointing forwards. It was curved so as to lie transversely in the bone, intervening between the roots of the normal incisors and the nasal cavity, and with its crown directed towards the left. BALLANTYNE (xxvi.) deals with the subject of *congenital teeth* (antenatally cut teeth), which he says are rare; they are generally upper incisors, but may be lower. Very rarely they are molars. Other buccal or facial malformations may accompany them. They are generally due to premature cutting of the tooth, but may be the result of a true ectopia of the dental follicle and its contained tooth.

VI. THORAX.

APERT (xxvii.) describes an interesting condition of the *great vessels* in a child which had survived its birth four months, though much cyanosed throughout that time. The heart apparently possessed but one ventricle, but a careful examination showed that the two were present,—that of the left side being greatly atrophied, whilst the right was much hypertrophied. The aortic orifice was absent, and so was the ascending aorta as such, and there was a persistent foramen ovale. The pulmonary artery gave branches to the lungs, and then continued as the remainder of the aortic arch and descending aorta. From the upper part of the arch thus formed there originated a single trunk, which bent over to the right (the fourth left arch), and gave off the left carotid and subclavian and the right carotid, and terminated as the right subclavian. From its under surface, and between the origins of the vessels of the two sides, there came off a small branch, which passed behind the pulmonary artery, arrived at the base of the heart, and there divided to form the two coronary arteries. This small branch represented the missing (ascending) part of the aorta. Thus the carotids and subclavians and coronary arteries received their blood by a retrograde current through the atrophied part of the aorta. A table is given of 20 similar cases (15 of which were amongst the 106 malformed hearts described by Thérémín). The cavity of the left ventricle is always considerably atrophied, and was absent in one case. The mitral orifice and valves are always much reduced in size (absent in 4 cases). The foramen ovale is patent except in two of the cases, and the pulmonary artery is enlarged. The other general conditions are the persistence of the ductus arteriosus and the atrophy of the arch of the aorta. BELLOT (xxviii.) narrates what is apparently a very similar case, though the condition is not so fully described.

SCHMIDT (xxix.), dealing with the subject of normal *polymastia*, refers to O. Schultze's observation as to the existence of a milk-line or groove in the embryos of pigs, etc. His observations, made with a view of ascertaining whether a similar structure existed, at a corresponding age, in the human foetus, have given negative results. By making sections, however, he found that supplementary gland anlagen

exist in the embryo both above and below the site of the normal breast, and these in greater numbers the younger the embryo examined. Those lying cranially to the site of the normal breast are mostly also lateral to it; those caudally, mesial; and all were confined to the upper thoracic region.

VII. ABDOMEN.

VALENTI (xxx.) describes a case of *displaced left kidney* of a female infant. The right kidney was normally situated, but the left was placed over the aperture of the pelvis, and transversely, so as to lie across the aorta, its arteries and veins being superficial. The suprarenal, as usual, was in its normal position. LATRUFFE (xxxi.) describes a similar case in which the left kidney was displaced so that its upper border was on a level with the 4th sacral vertebra, and its lower rested upon the aponeurosis of the obturator internus. It hung longitudinally, with its pelvis directed towards the left, the ureter crossing it anteriorly. The vein passed to the right common iliac. The larger of its two arteries came from the left internal iliac, and the smaller from the bifurcation of the aorta. The suprarenal was in the normal position.

CHRÉTIEN (xxxii.) narrates a case of *absence of the left kidney*, and JOLLY (xxxii.) one of *absence of the right*; also a second of a horseshoe-kidney which possessed three hiluses. MORESTIN (xxxiii.) describes an *anomalous arrangement of the large intestine* in a man aged 30. There was a Meckelian diverticulum. The small cæcum was provided with a long mesentery, and floated loose amongst the small intestines. The colon then passed up in the normal manner, and formed its transverse and descending portions. At the level of the left kidney, the latter turned sharply across the abdomen and reascended, passing behind the ascending portion and lying on its right side. Arrived at the liver, it again turned upon itself and descended to the right of the last-mentioned portion to the right iliac fossa, where it became the rectum. There were thus three coils of large intestine on the right side of the abdomen. BAGOURD (xxxv.) describes a case of *atresia* of the small intestine in an infant. The gut for 3 or 4 cm. was reduced to the condition of an impermeable cord. Above this was in the interior an elongated crest or ridge, corresponding to the attachment of the mesentery, which was covered with small papillomatous elevations. Narrow above, it enlarged so much below as to fill almost the entire lumen of the intestine. It was formed by an infolding of the mucous and muscular coats, the former prevailing, and being provided with much more marked glands than the rest of the canal. A somewhat similar case is described by TRUMPP (xxxvi.), the infant being one of twins (the other was normal). On opening the abdomen, the stomach and upper part of the duodenum were seen to be enormously dilated. Below the Vaterian papilla, the duodenum was represented for a short distance by a thick, white, fibrous cord, below which, again, the intestine was of normal size. V. WINCKEL (xxxvii.) describes a case of *atresia ani* where the rectum ended in a cord below the bladder, which it did not enter. There was an abnormally large penis.

KÜTTNER (xxxviii.) describes a museum specimen of *double penis*. The bladder was single, and so was the urethra as far as the lower end of the verumontanum. Here there was a minute communication with the rectum, below the openings of the ducti ejaculatores. Owing to the condition of the specimen, it could not be determined whether the child had possessed an anus. Beyond the verumontanum the urethra divided into two portions, which were provided each with a bulb, and entered two complete penes. The label on the specimen stated that the scrotum was double, and contained one testicle.

V. WINCKEL (xxxix.) describes a case of *pregnancy in the left horn* of a completely *divided uterus*. There was also a vaginal septum, and the child was born with double pes varus,—as he thinks, from the pressure of the small cavity. BALLANTYNE (xl.), dealing with the subject of so-called *epispadias in the female*, says that true epispadias in the female is a very rare condition; including doubtful cases, only 33 observations have been recorded. It consists in the absence of a greater or smaller part of the anterior urethral wall, with the division of the clitoris into two parts, and the presence of a median groove or gutter in the region of the anterior commissure of the vulva; the symphysis pubis is usually closed, and so is the anterior bladder wall. In its least marked form (clitoridian epispadias) the urethra simply opens above the clitoris instead of below it; but in all the other forms (sub-symphysial and retro-symphysial epispadias and sub-symphysial vesical exstrophy) there is a splitting of the clitoris and the existence of the median furrow. The malformation is most probably due to a mal-development of those parts of the anal plate to which Tourneux has given the names “bouchon cloacal” and “lame uretrale.” VANVERTS and RAMOND (xli.) describe the case of an infant whose *belly was distended with fluid*, puncture being necessary before delivery could be effected. On examination, the liver was found to be very large, and the microscope showed that it was much invaded with fibrous tissue. There was no evidence of syphilis, tubercle, or alcoholism in the parents.

VIII. EXTREMITIES.

MOUCHET (xlii.) describes a case in which the right hand of a five-months foetus was affected with *brachydactyly* of all the fingers except the thumb, which, like the fingers of the left hand, was normal. The nails were all perfectly developed. A longitudinal section of the whole index finger showed that the metacarpal was quite normal, but the phalanges were only represented by a small cartilage, which apparently represented the base of the first phalanx. The structure presented some peculiarities. The cartilage cells were grouped in small masses, between which there existed tracts with cells, and having a fibrillar appearance. The fibrils did not stain with carmine, were parallel, and did not anastomose. The extremity of the digit representing the other phalanges was formed of connective tissue, with vessels. It was furnished with the usual appendages of the skin, but contained no cartilage. PICQUÉ (xliii.) describes a

case where the *thumb*, as such, *was absent*, the radial border of the hand being in a straight line with that of the forearm. A diminutive thumb was attached to the side of the index by a skin pedicle, containing a vessel. It was 3 cm. long and 4 cm. in circumference, and was formed of two rudimentary phalanges, united by an articulation. LEBOUCC (xliv.) gives three cases of malformations affecting the hands. (1) symmetrical. The 2nd and 3rd digits appear to have only two phalanges, but on dissection it was found that the 2nd digit, though so short, had four phalanges, the 1st and 3rd being short and nodular, and the 2nd and 4th normal in appearance. The 1st and 2nd were, as shown by the muscular attachments and other facts, equivalent to the basal phalanx. It is, then, the 1st phalanx which was divided, but the condition was not one of a simple epiphysial separation, since the second segment of the index and the first and second of the medius were bones with clearly distinct diaphyses and epiphyses. (2) Brachydactyly of all the digits of the hand without hyper-phalangy. In the thumb it is the metacarpal which was reduced, in the others the second phalanx. (3) Left foot. Brachydactyly of the three inner toes, affecting the metatarsal in the hallux and the middle phalanx in the others. He thinks that the middle phalanx is the absent member in the hallux and pollex, and that this segment is in course of disappearance elsewhere, *e.g.*, in the minimus, where Pfitzner found it united with the distal phalanx in 17 out of 301 toes which he examined. There is, he thinks, a tendency in the hand and foot towards a reduction in the rays, first in length, and then in the number of their constituents; and this reduction is chiefly felt in the intermediate phalanx. That of the first is gone in the hand and foot, and that of the little toe is going. In the hand the process is less advanced than in the foot, but in both it is the lateral rays which are being specially reduced. TILANUS (xlv.) describes a case of *ectrodactyly* in a man aged 36. R. hand, the ii, iii, iv metacarpals are normal, the i, v and the 1, 2, 5 fingers are absent. The 3 and 4 fingers are present, but united by skin. L. hand, the iii, iv, and v (?) metacarpals are present; i and ii are absent, and also 1, 2, 3, and 5 fingers. R. foot, the i, ii, iii, iv metatarsal are absent with their toes; the v metatarsal and toe are present. Several other members of the family show similar malformations. VALENTI (xlvi.) adds three further cases to the literature of *supracondylar process*.

JOACHIMSTHAL (xlvii.) gives several cases of *abnormalities of the extremities*. (1) The mother had congenital dorsal luxation of the two thumbs, which were rudimentary, and possessed a much reduced musculature. The eldest child (m.) had the right thumb removed after birth. It was atrophic, and attached to the index. On the left side the radius, thumb and its metacarpals were absent, and the whole forearm was shorter than the right. The second child (m.) had no right thumb, but a supernumerary digit of two phalanges was attached to the radial aspect of the first phalanx of the index, which no doubt represented it. The left upper extremity was atrophic in all its parts, including the shoulder girdle. The upper end of the radius was absent, not reaching to the humerus; the thumb and its metacarpal

were absent, and the arm was fixed in a position of pronation. The third child (f.) had the terminal phalanx of the thumb twisted so as to look to the ulnar side of the hand. The fourth child (f.) had on each hand five metacarpals and five tri-phalanged digits. (This is another instance of the rare condition of a tri-phalanged thumb, other cases of which have been mentioned in a previous report, and in a paper by the present reporter in this *Journal*.) It is interesting to note that malformations of excess and defect both exist in this family. V. WINCKEL (xlvi.) describes an interesting case where an *amniotic band* was found *encircling the arm of a fœtus*, which it had nearly severed. This adds another to the cases where the amniotic band has been caught in the act, so to speak, of performing an intra-uterine amputation. FÉRÉ (xlix.) alludes to a condition of *subluxation of the hand* forwards, characterised by an undue projection of the lower end of the radius on the dorsal surface of the wrist. He thinks that this is developmental, because it appears at adolescence and is hereditary. It is more frequently met amongst epileptics than amongst the healthy. He has also found that epiphysial exostoses of the sternal end of the clavicle are more frequently met with amongst the mentally unsound.

EBSTEIN (l.) narrates an instance of *syndactyly* of both hands and the left foot in a child, five generations of whose ancestors also had exhibited similar malformations. In both hands the 3 and 4 fingers were united, the first and second phalanges by skin, the ungual by bony union. There was a single nail, which possessed two lunulæ. The left had its 4 and 5 toes united by skin for their first two phalanges; and the fifth toe bore a rudimentary sixth digit. CHAILLONS and DESFOSSES (li.) described the case of an infant æt. 3, in which the *leg segment* was absent. The right lower extremity consisted of a thigh of the normal size, which terminated by a representative of the foot, possessing two toes, one of which bore a nail. The femoral condyles were present, but there was no trace of the bones of the leg. The toes contained metatarsals and phalanges, but there were only rudimentary tarsal bones. REGNAULT (lii.) describes certain alterations in the *femora* in cases of *congenital luxation*. The pilaster, which is posterior in a normal femur, is most generally carried outwards. In any case, the greatest diameter of the femur is that which bears the pilaster, so that when the latter is on the outer side, this diameter is transverse and not antero-posterior; and the femur is flattened in an antero-posterior direction. The pilaster is composed normally of two ridges and a groove between them. The external ridge generally remains, the internal has diminished or has disappeared. It seems as if the disappearance of the internal ridge of the pilaster is the result of the atrophy of the abductors and the diminution of the internal surface of the vastus externus, which is explained by the gait. The knees are generally carried inwards, the thighs are rotated internally. This attitude brings the pilaster outwards and relaxes the adductors.

BALLANTYNE and ELDER (liii.) describe a case in which a mother and child were both affected with *hereditary tylosis—palmæ et plantæ*.

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NOTES ON THE DISSECTION OF A CASE OF DOUBLE
KNOCK-KNEE. By JOHNSON SYMINGTON, M.D., F.R.S.E.,
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(Abstract.)

THE body of a girl aged 17 years, with double knock-knee, was dissected. The deformity had commenced about two years before her death. It was therefore evidently a case of genu valgum adolescentium.

The body was very thin, and death was from tubercular disease.

The degree of knock-knee was very nearly the same in both limbs. With the knee fully extended, a straight line drawn from the top of the head of the femur to the centre of the ankle-joint passed 6 inches to the outer side of the centre of the knee-joint, instead of, as in a normal limb, corresponding to this point. Again, the external angle

¹ This paper is printed *in extenso*, with a plate, in *Trans. Roy. Acad. Medicine, Ireland*, vol. xiv., 1896.

at the knee between the long axis of the shaft of the femur and that of the tibia is usually about 170° , while in this case it was 120° in the right limb and 118° in the left. The feet were inverted to an abnormal degree, as in the condition termed *talipes varus*.

Amongst the muscles in the region of the knee, the sartorius and gracilis were displaced to the greatest extent, as they descended behind instead of on the inner side of the knee. On looking at the knee from behind, the sartorius was seen to lie $1\frac{1}{2}$ inches external to the most prominent point on the inner aspect of the internal tuberosity of the femur, while the gracilis descended behind the knee, opposite the outer boundary of the inter-condyloid notch. The semi-tendinosus and semi-membranosus were also displaced outwards, though not nearly to so great an extent as the other two muscles. The tendon of the adductor magnus inserted into the upper part of the internal tuberosity of the femur was much more prominent and superficial than normal. The biceps was normal, except that it was rather more prominent than usual, and was at once rendered tense on any attempt being made to adduct the leg at the knee. The insertion of the popliteus and the tibial origin of the soleus were uncovered to a large extent by the gastrocnemius. This is partially due to the feeble development of the latter muscle, but also to the projection inwards of the internal tuberosities of the femur and tibia.

The relations of the popliteal artery to the bone were greatly altered. Thus it crossed the popliteal surface of the femur much nearer the outer than the inner border passed on to the back of the external condyle close to its outer edge, and then descended behind the superior tibio-fibular articulation, close to the level of the outer edge of the top of the tibia. The distance between the artery and the popliteal surface of the bone was further increased in this case by the vessel lying on the back of the external condyle instead of in the hollow between the two condyles. A finger could readily be passed between the bone and artery without disturbing the latter, for nearly two inches above the external condyle, and opposite the lower part of the popliteal surface, the artery was $\frac{5}{8}$ of an inch from the bone.

The deep branch of the anastomotic of the femoral passed down as usual just in front of the tendon of the adductor magnus, but its superficial branch, which accompanies the long saphenous nerve, was displaced to the back of the knee. The two superior and the azygos articular branches arose by a common trunk, which passed inwards to about the middle of the back of the joint before dividing. The superior external articular continued in the same direction as the common trunk for a short distance and then turned outwards, passing between the popliteal artery and the femur to be distributed as usual. At the point where the external articular artery turned outwards it was $\frac{5}{8}$ of an inch internal to the popliteal vessel. The external and internal popliteal nerves were shifted outwards to even a greater extent than the popliteal artery. This was especially the case with the internal popliteal, which at its origin from the sciatic was situated in a plane external to that of the outer surface of the lower part of the shaft of the femur. As the nerve descended it crossed the outer

head of the gastrocnemius obliquely from without inwards, and came in contact with the popliteal artery near its termination.

In this specimen the upper end of the femur and almost the whole length of its shaft appeared to be normal, and showed no unusual curves, the changes in the form of the bone being confined to the neighbourhood of the lower end of the diaphysis and its epiphysis. When the femur was placed with the long axis of its shaft vertical, the internal condyle lay at a plane 1 inch lower than that of the external. In a young and normal femur of almost exactly the same length the author found that the downward projection of the internal condyle was only $\frac{1}{4}$ of an inch more than that of the external. It has been frequently asserted that in cases of knock-knee the internal condyle is abnormally increased in length, but Mikulicz has endeavoured¹ to show that this is not the case, the marked prominence of the internal condyle being due to an increased growth of the inner part of the lower end of the femoral diaphysis, so that the epiphysis is placed against a surface looking obliquely downwards and outwards. It is evident that this point can only be determined with accuracy by the examination of the femur in cases of knock-knee before the epiphysal cartilage has become ossified, and preferably shortly before adult life, when this cartilage is thin, so that the line between diaphysis and epiphysis can be sharply defined.

Professor H. E. Clark² made a series of observations of normal adult femora to determine this question, and he came to the conclusion that the internal condyle is, as a rule, $\frac{1}{4}$ of an inch longer than the external. These measurements, however, represent the greatest vertical extent of the epiphysis on the inner and outer sides, and not simply the vertical length of the condyloid articular surfaces. They were apparently made on the inner side from the adductor tubercle, and on the outer from just above and in front of the depression for the outer head of the gastrocnemius. In these two places the epiphysal line attains its highest level above the condyles. On the posterior aspect of the femur the epiphysal line is situated immediately above the articular surface of the external condyle, but is fully $\frac{1}{8}$ of an inch above that of the internal condyle, and then ascends to the adductor tubercle, which is $\frac{1}{4}$ of an inch above the level of the top of the articular surface of the internal condyle. The vertical extent of the posterior part of the two condyloid articular surfaces will be found to be practically equal, although the vertical height of the epiphysis is $\frac{1}{4}$ of an inch greater on the inner than on the outer side of the bone.

Mikulicz draws one transverse line at the back of the femur, just above the posterior part of the two condyles, and another at the level of the lowest part of the two condyles, and he states that these two lines are parallel, or very nearly so, hence he regards the two condyles as of equal length.

In the author's specimen of knock-knee the two condyles, measured

¹ Die seitlichen Verkrümmungen am Knie und deren Heilungsmethoden. v. Langenbeck's *Archiv f. klin. Chirurgie*, Bd. xxiii.

² Quoted in Macewen's "*Osteotomy*," p. 44.

by Clark's method, were found to differ from each other in height only $\frac{1}{8}$ of an inch, the internal being $1\frac{1}{8}$ inches and the external 1 inch; and by Mikulicz' plan were equal. Compared with normal bones of the same size, there was no increased length of the internal condyle, if anything slightly the reverse, while at the same time there was no shortening of the external. Further, the shaft of the bone was not abnormally curved, so that the excessive downward projection of the internal condyle, when the shaft of the bone was held with its long axis vertical, was due to an increased growth of the inner side of the diaphysis. These results support the views of Mikulicz.

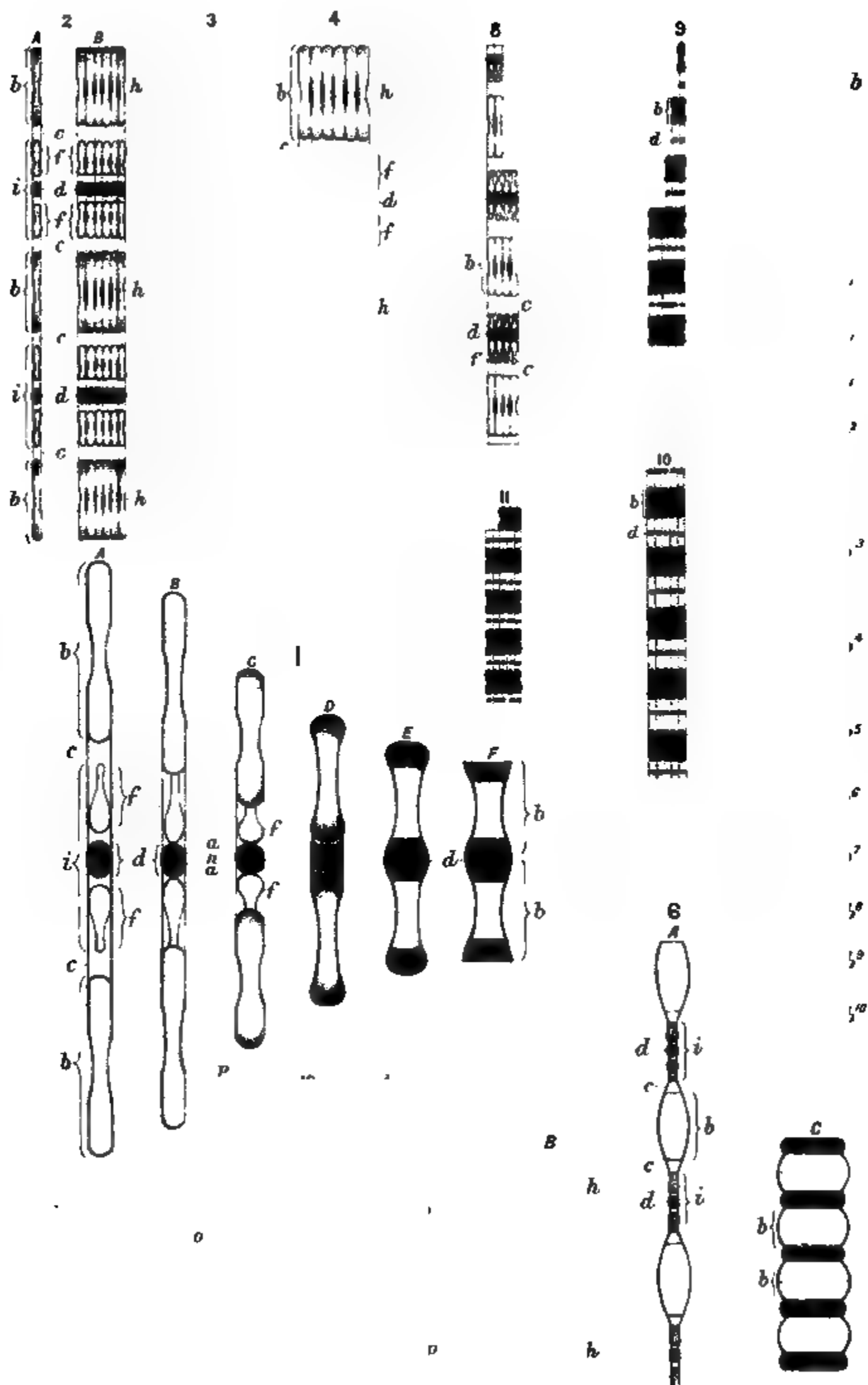
An examination of the tibia showed that it contributed even more than the femur to the production of the in-knee deviation, and that this was due entirely to an excessive growth of the inner side of the upper part of its diaphysis. Thus, with the shaft vertical, the inner edge of the upper surface of the tibia projected $1\frac{1}{8}$ inches above the level of the outer edge, and on coronal section the epiphysis was rather thinner on the inner than on the outer side.

In both tibia and femur the layer of compact bone was thinner than normal, and at the extremities the spaces in the cancellous bone were much larger than usual. This was especially the case towards the inner side of the bones. The epiphysial cartilage at the lower end of the femur presented appearances which are characteristic of rickets. In some places it was considerably thickened, and formed various irregular projections, almost all of them being directed towards the diaphysis. There were also various islands of cartilage embedded in the bone above and below the epiphysial line.

There was no deformity in the bones of the upper limb except some swelling of the extremities of the long bones, and slight rachitic changes in the epiphysial cartilages. The vertebral column and ribs were normal, but the pelvis was imperfectly developed and deformed. The conjugate diameter of the pelvic inlet was considerably greater than the transverse, and the right innominate bone at the ilio-pectineal eminence was bent inwards.

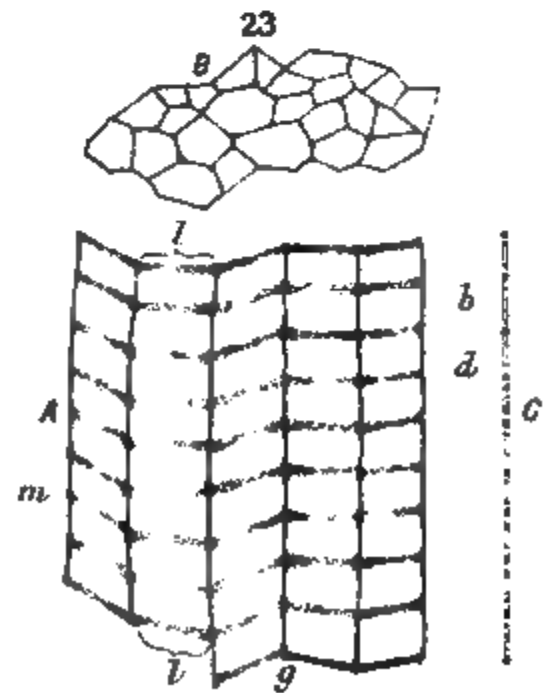
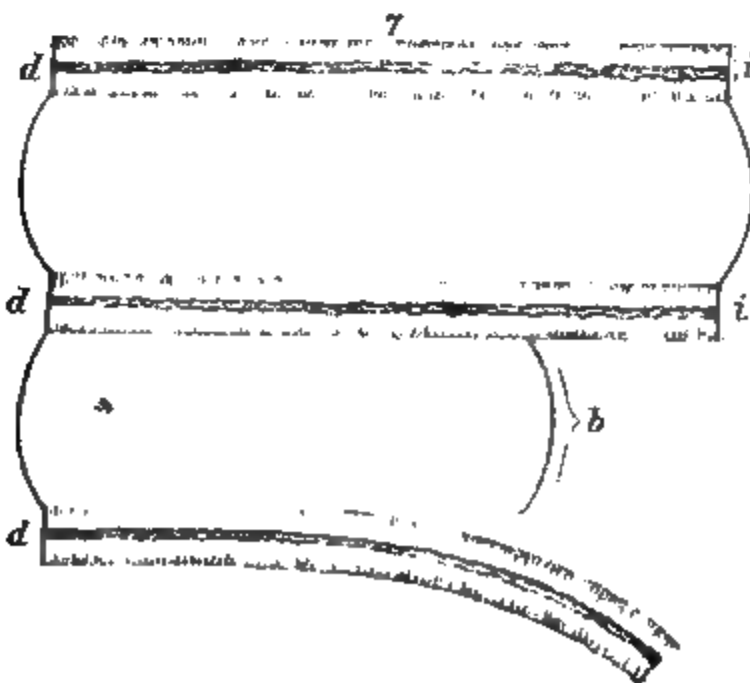
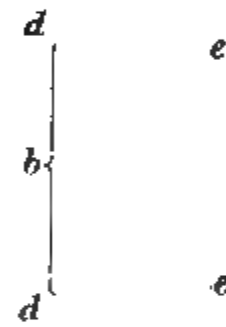
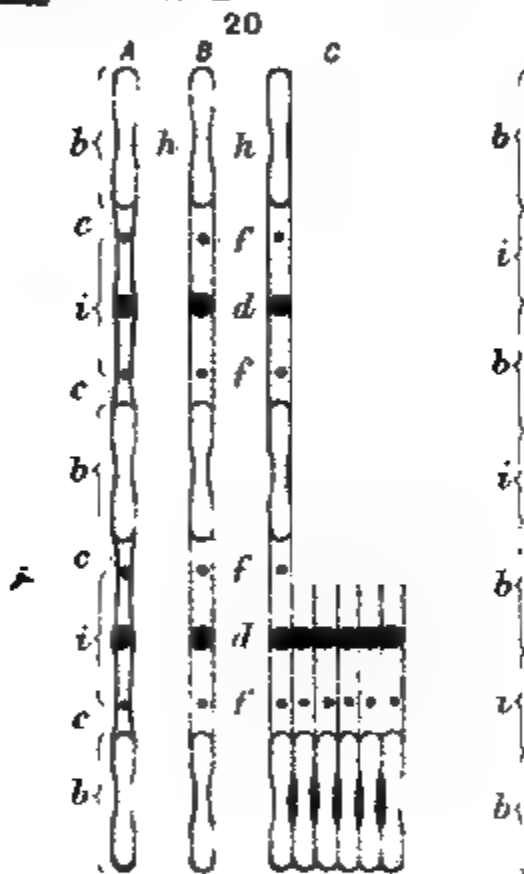
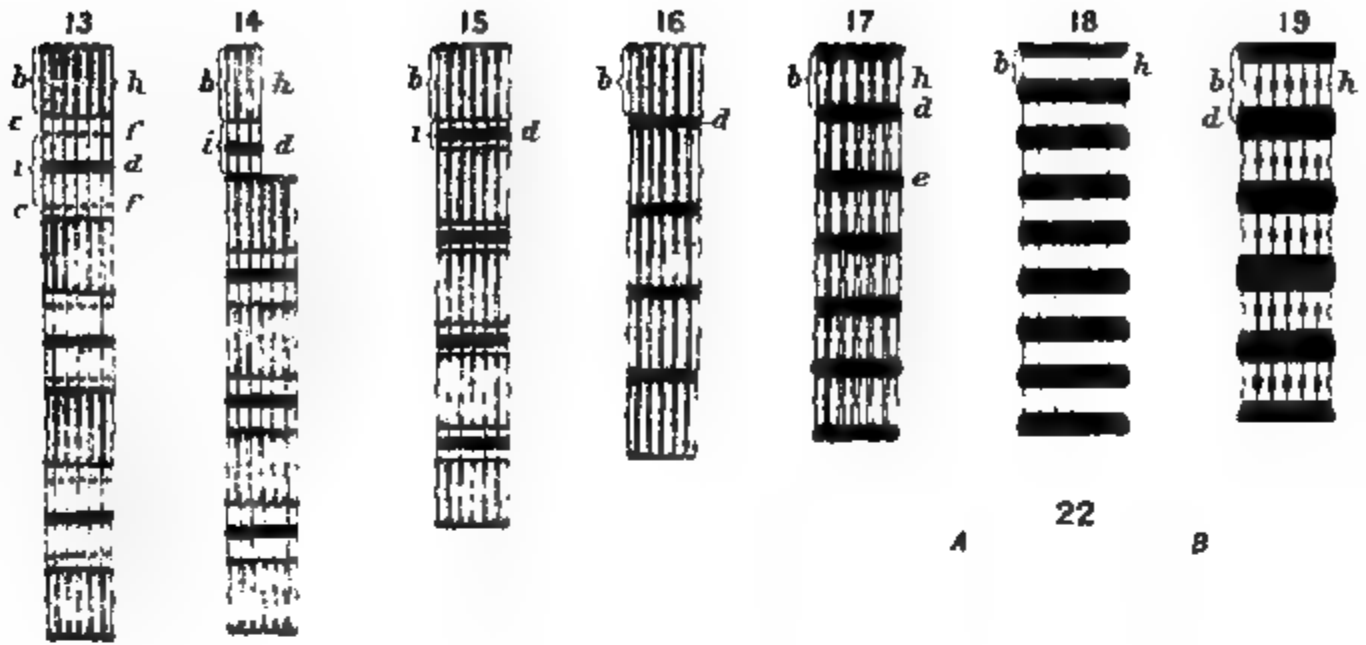
The spine on the inner side of the upper part of the shaft of the tibia, generally found in cases of knock-knee, was well marked in both legs. Its mode of production is obscure. It was situated $\frac{1}{2}$ inch below the level of the epiphysial line, and behind and above the insertion of the sartorius, gracilis, and semi-tendinosus, but the lower part of the internal lateral ligament of the knee was attached to it, and its development is possibly due to the strain upon this structure.

The articular cartilage covering the femur, tibia, and patella at the knee-joint appeared to be quite normal. The muscles of the body generally were feeble and the ligaments of the joints lax. On attempting to straighten the knee the ilio-tibial band, the biceps, and the external lateral ligament became tense, and resisted the reduction of the deformity.



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MUSCLE.

FIG. 1.

Fibrils of extensor muscle of crab's leg, uncontracted and fully extended, showing Bowman's, Dobie's, and Flögel's elements. Formol, heliocine, glycerine Zeiss μ , homogen. Obj. Compare Plate XII., figs. 3 and 4.

FIG. 2.

Fibrils of muscle of crab's leg, uncontracted and unextended, showing Bowman's and Dobie's elements. Flögel's elements are not seen. Müller and sp., heliocine, balsam. Zeiss μ , homogen. Obj. Compare Pl. XII., fig. 14.

FIG. 3.

Bundle of semi-contracted fibrils from muscle of crab's leg, showing decided shortening of the interval between ends of Bowman's elements, also some shortening of Bowman's elements and the chromatin beginning to accumulate at their ends. Müller and sp., eosine, glyc. 4 mm. apochrom. Obj.

FIG. 4.

A further stage of contraction of crab's leg muscle, showing bundles of fibrils crossed by dim, coarsely granular looking bands, formed by adjacent ends of Bowman's elements swollen with chromatin and Dobie's elements between them, although invisible. Hensen's line is seen crossing the light band, now consisting of the shafts of Bowman's elements. Mode of preparation and Obj. same as in fig. 3.

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FIG. 5.

Fully contracted muscle of crab's leg, showing complete reversal of the stripes.
 The light bands consist of the shafts of Bowman's elements, from which the chromatin has entirely moved to the ends, now much swollen and bulging at the border of the fibre. Hensen's line is seen in the middle of the light bands. At the margin of the figure a fibre is seen with a different focus, showing reversal of the light and dim appearances of the bands, resulting from the convexity formed by the swollen ends of Bowman's elements and the concavity due to their shafts. Mode of preparation and Obj. same as in figs. 3 and 4.

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FIG. 6.

Contracted muscle photographed with Zeiss 2 mm. apochromatic Objective from same preparation as fig. 5. The Objective has resolved the dim bands, which are now seen to have the composition shown at an earlier stage in fig. 3.

FIG. 7.

A bundle of contracted fibrils photographed with Zeiss $\frac{1}{8}$ homogeneous Objective from same preparation as fig. 5.

Collotype.
J. J. BRIDGEMAN,
51st Lane, 352 Queen Victoria St.,
London.

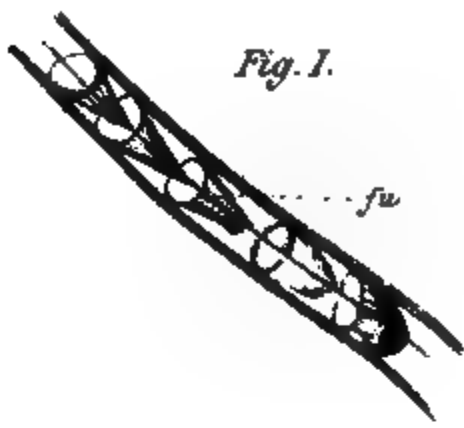


Fig. 3.

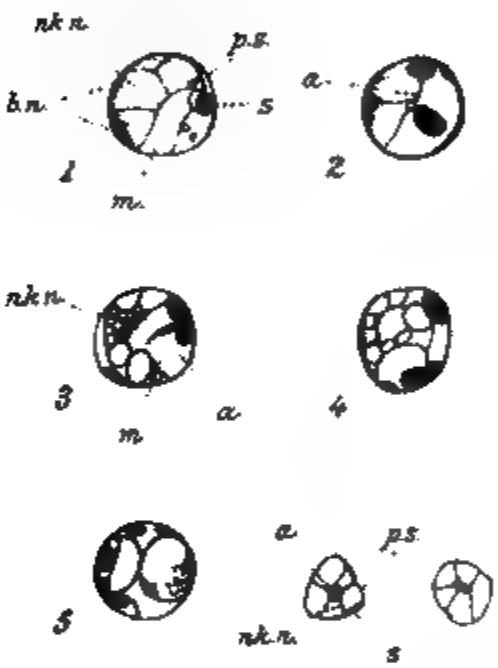


Fig. 4.



Fig. 5.



Fig. 6.



Journal of Anatomy and Physiology.

ON THE ACTION OF INFUSED BEVERAGES ON
PEPTIC AND PANCREATIC DIGESTION. By
JAMES W. FRASER, M.D., C.M. Ed., M.R.C.S. Eng.

THE following paper embodies the results of a series of experiments continuing those published in this *Journal*, vols. xviii. p. 13, xx. p. 361, and xxi. p. 337.

The experiments were commenced several years ago, and have remained unpublished for lack of the time to properly examine them, but may now be described, if only to complete the series; although the researches of Ewald and Boas, of Hayem, and of their pupils, in the intervening period, have thrown fresh light on the processes of digestion.

The experiments detailed in vol. xviii. were on the action of various beverages on peptic digestion, and the results were estimated from the amount of organic matter, nitrogenous and otherwise, which, after digestion, passed through parchment paper dialysers.

In vol. xx. the same results were re-examined by a different process, the amount of nitrogen contained in the dialysed organic matter being taken as the basis of calculation, only peptones and nitrogenous extractives being thus estimated; in vol. xxi. the action of the three typical beverages on the peptic and tryptic digestion of the proximate principles of food stuffs was examined, digestion being carried on in a new apparatus, but the estimation of the peptones by the nitrogen process.

In the present series of experiments the digestive processes were carried on in the same apparatus as in those last mentioned, and in that paper the arrangements are fully described and the grounds on which they were based set forth. In vol. xx. the process of estimating the organic nitrogen dialysed is described,

and that process was followed in these experiments. In the cases of pancreatic digestion, where glucose had to be estimated, Fehling's process was used.

Before describing the experiments it must, as in former papers, be premised that all vital phenomena, such as secretion and muscular movement, are ignored, and, by the nature of the experiments, attention is paid only (*a*) to the actions of a given quantity of each beverage on the proteolytic action of a given quantity of artificial gastric juice, and on the proteolytic and amylolytic action of a given quantity of artificial pancreatic juice on a given weight of albuminoid or carbohydrate food stuff; and (*b*) to their actions on the dialysis of the resulting peptones and glucose.

Absorption from the stomach and bowel can hardly be considered as a simple osmosis: vital action of cells takes a part in it, as evidenced by the dehydration of peptones as they pass through their walls, and by the absorption of fats into the intestinal epithelial cells.

With such more complicated actions these experiments have nothing to do.

It may be convenient to give a brief sketch of the process of experiment, referring to the former papers for details. The peptic fluids employed were two:—

(*a*) In one set of experiments, a personally prepared fluid having the following composition:—

Pepsina Porci, 5 grms.

Hydrochloric acid, 10 per cent. solution, 2 c.c.¹

Distilled water to 100 c.c.

The whole digested together for twenty-four hours at 37·7° C. and filtered.

¹ Ewald and Boas have shown (*Berlin. klin. Woch.*, 1886, pp. 33, 50, 113; *Archiv für Path. Anat. und Phys.*, ci. p. 325, and civ. p. 271) that peptic digestion in the earlier stages proceeds in presence of lactic acid, and that hydrochloric acid only appears later; and are confirmed by Ellenberger and Hoffmeister (*Arch. für die Ges. Phys.*, xli. p. 484), Landwehr (*Arch. für Anat. und Phys. Abth.*, 1890, p. 280). Poulet (*Arch. de Phys.*, 1888, 1st Oct.) states that hippuric acid is the only one present during gastric digestion in the human subject. Boas (*Zeitschrift für klin. Med.*, xxv. p. 285) has shown that the lactic acid is not secreted, but derived from food fermentations, and this is confirmed by Cahn and Mehring (*Berlin. klin. Woch.*, 1886, p. 682), Wagner (*Vratch*, 1893), and Lockhart Gillespie (*Jour. of Path. and Bact.*, Feb. 1893, and *Jour. of Anat. and Phys.*, xxvii. p. 195). It was in accordance, therefore, with the majority of opinions that hydrochloric was the only acid used in these experiments.

(b) In a second set, one prepared from Benger's Liquor Pepticus:—

Liquor Pepticus, 20 c.c.

Hydrochloric acid, 10 per cent. solution, 2 c.c.

Distilled water to 100 c.c.

The Liquor Pepticus was neutralised with sodic carbonate before mixing with the hydrochloric acid and water.

The pancreatic fluids were also two in number: (a) was made from Kühne's pancreas powder, personally prepared (pig's pancreas exhausted with alcohol and ether and dried at 37·7° C.); the powder was not weighed, but digested at the room temperature for twenty-four hours in 2 per cent. hydrochloric acid to convert all zymogens into ferments, and then, having been made alkaline to the extent of 1 per cent. with sodic carbonate, the mixture was digested for one hour at 37·7° C. and the solution filtered off. Sufficient fluid was made to serve for all the experiments in which it was used; (b) the second pancreatic fluid was Benger's Liquor Pancreaticus.¹

The following beverages of the strengths given were subjected to experiment:—

Of the teas (infusions of prepared leaves), ordinary black tea, a very cheap congou tea, green tea, a compressed tea from Russia, tea infused with water made alkaline with a trace of sodic carbonate, maté and coca, all of the strength of 2·5 grms. to 100 c.c. of water,² the water being boiled and the leaves infused in it for twenty minutes.

Of the coffees (infusions of prepared seeds), ordinary coffee, coffee prepared as closely as possible after the Arab method as described by Palgrave,³ coffee with chicory (4 parts of coffee to 1 of chicory), all of the strength of 3 grms. to 100 c.c. of water,⁴ boiled, and, except in the case of 'Arab' coffee, poured through the powder placed in a suitable strainer. A 15 per cent. coffee was also used.

Of the cocoas (gruelly mixtures of roasted ground seeds and water), Epps's cocoa, as a type of those preparations, in which the fatty seed is diluted with starch and sugar, of the strength of 7 grms. to 100 c.c. of water,⁵ the water boiled and the powder simply mixed with it; Schweitzer's cocoatina, to represent those in which most of the fat has been removed, prepared in the same way as the last, but of the strength of 1·5 grms. to 100 c.c. of water;⁴ chocolate, 6·5 grms. to 100 c.c. of water, the powdered chocolate boiled in the water for a few minutes; khola chocolate, prepared in the same way and of the same strength; and guarana, of the strength of 5 grms. to the 100 c.c. of water, and prepared like the cocoas.

Two other beverages, derived from the *Theobroma cacao*, were also

¹ Used as well as Kühne's pancreas powder by Sheridan Lea (*Jour. of Phys.*, 1890, vol. ii. p. 227).

² These beverages are weaker than those used by Sir W. Roberts in his experiments (*Dietetics and Dyspepsia*, p. 28), but are founded on approved culinary recipes.

³ *Central and Eastern Arabia*, 6th edition, p. 36.

⁴ Weaker than in Sir W. Roberts' experiments, *loc. cit.*

⁵ Stronger than in Sir W. Roberts' experiments, *loc. cit.*

used in the experiments, viz., the infusion of the seeds or nibs, 5 grms. to the 100 c.c. of water, infused for an hour and a half at a temperature of about 80° C.; and that of the husks (known as 'miserables'), of the same strength and prepared like a tea.

These beverages were divided, for the purposes of the experiments, into two classes,—a typical and more important, numbering only three, ordinary tea, ordinary coffee, and Epps's cocoa; and a less important, containing the other beverages. The more important had their effect on digestion tested with white and yolk of egg, roast beef, boiled salt beef, roast mutton, ham, fowl, fish, bread, and potato, with both the personally prepared and the Benger fluids. The less important were tested with white of egg, and a few with beef and with bread, with the Benger preparations only. The meats used were cooked in the ordinary way and finely minced, the yolk and white of egg hard-boiled and pressed through a sieve to form threads and the bread finely crumbled. With each batch of three beverages a control experiment, with water in the same proportions and under identical conditions, was performed. The process of digestion was as follows: Usually 2 grms., but sometimes 5 grms., of the meat were digested with 20 c.c. of the peptic fluid and 10 c.c. of the beverage—or of water in the control experiments—in a small dialyser,¹ suspended in a beaker containing 120 c.c. of .2 per cent. hydrochloric acid solution, the whole being kept at 37.7° C., and the arrangements for stirring and maintaining an even level inside the dialyser and out being the same as described in vol. xxi. Digestion having gone on for six hours, the dialysate in the beaker was removed and kept for examination. The contents of the dialyser were made alkaline to the extent of 1 per cent. of sodic carbonate and 5 c.c. of the pancreatic fluid added, the dialyser was replaced in the beaker, now containing 140 c.c. .1 per cent. sodic carbonate solution, and digestion continued for six hours at 37.7° C. The dialysate was again removed and put aside for examination, and its place taken by 140 c.c. of distilled water, and the whole apparatus heated until the temperature in the dialyser was raised to 80° C. to destroy the ferments, and dialysis allowed to continue for twenty-four hours, the apparatus cooling to the room temperature.

For the estimation of the peptones produced the nitrogen process was followed. Measured quantities of the dialysates in each stage were evaporated to dryness with a little purified sodic chloride (to make them manageable), and weighed. Weighed quantities were incinerated with soda lime in combustion tubes, and the evolved ammonia received in a special apparatus and estimated by Nessler's process.

¹ Experiments on digestion carried on in dialysers suspended in acid or alkaline fluids, as the case may be, have been made by Kronecker (*Gschleidens Phys. Mit.*, p. 206), Wolffhügel (*Pflüger's Arch.*, 1873, p. 189), by Lockhart Gillespie (*Jour. of Path. and Bact.*, Feb. 1893), and by Sheridan Lea (*Jour. of Phys.*, 1890, vol. ii. p. 227), who compares the results of digestion in parchment paper tubes, with suitable mixing arrangements, with those of digestion in flasks or beakers, greatly to the advantage of the former.

The results were calculated by formulæ given with the description of the process in vol. xx., and were tabulated as 'Peptic,' 'Tryptic,' and 'Dialysis' results respectively; but from considerations detailed in that paper it was shown that the 'tryptic' results represent chiefly those of peptic digestion, and those in the 'dialysis' stage those of tryptic.

To eliminate error resulting from dialysable nitrogenous matter present in or resulting from the digestion of the digestive fluids or beverages, experiments were, as in the former series, performed with water and the beverages, but with no food stuffs, and the results, calculated for each stage and known as 'Factors,' were deducted from the figures obtained by the digestion of the food stuffs.

These 'Factor' figures are shown in Tables A, B, and D,—Table A containing the results with the personally prepared digestive fluids; Tables B and D those with the Benger preparations.

If the 'Totals' in the case of water as the beverage—that is to say, the nitrogen derived from the digestive fluids alone—are compared, it will be found in the four instances in which they appear in these tables that they do not greatly differ, nor is the difference very great in the various stages, except in the tryptic stages in Table D, which are nearly double of those in Tables A and B.

Examining next, in the same three tables, the figures under the heads of the various beverages, the 'Totals' which contain the nitrogen derived from the beverages and digestive fluids show five cases in which the results are smaller than that with water as the beverage in their own group, viz., cocoa (Table B), 15 per cent. coffee, khola paste, cocoatina, and guarana. In the case of chocolate the figure is identical with that with water as the beverage.

The five former figures indicate that not only has the beverage yielded little or no nitrogenous matter to digestion, but that it has also held back some of the nitrogenous matter of the digestive fluids from digestion or dialysis. It may, however, be noted that in the 'peptic' stage, in which the beverages would still contain their highly diffusible alkaloid, even they in no case fall behind the result with water as the beverage. The result with

15 per cent. coffee is small, because it was subjected to experiment at quite a different time from the rest, and presumably with digestive fluids of lower nitrogen strength, but even it in the peptic stage yields more nitrogen than not only the water experiment, but also that with ordinary coffee (Table B). The small results with the cocoa beverages are, however, susceptible of a different explanation, to be referred to later on. Between the experiments in Tables A and B with the same beverages, but different digestive fluids, there is a general correspondence, but the beverages in the former appear to have contained more nitrogen than those in the latter. The total amount derived from the beverage is in any case very small, never exceeding .0016 gm., and only reaching that amount in the result with coffee in Table A.

The results with coffee are greater than those with tea, because the latter precipitates some of the albuminoids of the digestive fluids, which the less astringent coffee does not; cocoa also produces this precipitate, and this helps to make its results so small. This precipitation, concealed in the case of unfiltered cocoa, was noticed in every case when tea was mixed with a digestive fluid, and did not appear to decrease as digestion proceeded.

The total dialysable nitrogen contained in each beverage is shown in Table C, and is very small, but still greater in the case of tea than that derived from the digestion of an equal quantity of the beverage, as shown in Table B, though less than that in Table A.

If the 'Totals' of the less important beverages, contained in Table D, be next examined, it is found that green tea yields to digestion nearly twice as much nitrogen as ordinary black tea, and that the addition of a trace of sodic carbonate to the infusing water causes the extraction of fully a third as much more nitrogenous matter, probably albuminoids insoluble in plain water. Coca also yields a highly nitrogenised beverage, and a cheap congou tea yields more nitrogen than ordinary black tea of good quality. All the cocoas have 'Total' figures fairly close together, the miserables (cocoa husk infusion) showing the largest amount of dialysable nitrogen.

Before examining the most important results of the digestion of meats—results contained in Tables E, F, G, H, and I—it may

be well to say a word about the principles on which this examination will be conducted. The 'actual result' tables, E, F, and H, show the amount of nitrogen in each case as determined by experiment, the 'Factor' of the beverage in question having been first deducted. On account of the difficulty of rapidly appreciating the meaning of such a mass of figures, a percentage method of tabulating has been followed in Tables E, G, and I: the result in presence of water as the beverage is taken as 100 per cent., the percentages in presence of the infused beverages being calculated from this. It is evident that, if some of the meat remained undigested at the end of the experiment, these percentage figures represent the digestive power of the mixture of beverage and digestive fluid compared with that of a mixture of similar quantities of water and digestive fluid.

The percentages will be found to be both above and below 100 per cent.: in the former case the beverage appears to assist digestion or dialysis, or both; in the latter, to retard one or both.

In arranging the beverages into those which assist or retard digestion, certain arbitrary groupings will be observed: all figures between 95 per cent. and 105 per cent. will, to allow for experimental errors, be taken to show that the beverage had no effect on the digestion of that meat; figures above 105 per cent. to show that it assisted, and those below 95 per cent. that it retarded, digestion; dividing these latter into two groups, (a) a 'slightly retarded' between 95 per cent. and 80 per cent., and (b) a 'decidedly retarded' below 80 per cent.

Examining Table E, which contains the results of the experiments with personally prepared digestive fluids, and looking first at the 'actual results,' it is found that there are several minus quantities among them.

These are the 'dialysis' results with bread and the 'tryptic' results in presence of coffee, and are cases in which the amount of dialysed nitrogen was less than the 'Factor' at that stage. An attempt to explain these figures will be made later; in the meantime it makes it impossible for bread to have any 'Total' results, and for percentages to be calculated from the minus results.

There are also two figures most noticeable in the percentage half of the table which will have to be disregarded, viz., the

enormous 'dialysis' result of beef digested in the presence of tea, and the increased 'Total' to which it gives rise. The dialyser was found to have leaked at this stage; hence the error.

If the 'Total' percentages are first considered, it is found that coffee assists the digestion of white of egg, and tea only slightly retards it, while coffee decidedly retards that of beef.

If the 'Peptic' results are examined, tea is found to slightly retard the digestion of white of egg and beef, and decidedly that of bread, while coffee assists that of beef, and does not affect that of white of egg and bread. In the so-called 'tryptic' stage, tea decidedly retards the digestion of all three foods, and coffee that of beef, while it does not affect that of white of egg. In the 'dialysis' stage tea does not affect the digestion of egg. Coffee assists this, but retards that of beef.

In Tables F and G are the actual and percentage results of the largest number of these experiments, many of the figures being founded on the average of a number of experiments, the whole Table F representing the actual results of 68 such experiments of three stages each, and of 24 of one stage each.

All these were made with the Bengel preparations; and before their results can be accepted as anything more than expositions of the efficiency of these preparations under different conditions, it must be shown that the results are, in a sufficient number of cases, parallel with those performed with the personally prepared digestive fluids whose composition and mode of manufacture are known. That this is no mere hypercritical demand for accuracy, but a practical necessity, will be seen when the experiments on tryptic and pancreatic digestion come to be considered.

In comparing the actual and percentage results in Tables E and G, those may be taken as confirming one another, which in both tables fall into the same classes of the four above described: 'assisted' (above 105 per cent.); 'unaffected' (105-95 per cent.); 'slightly retarded' (95-80 per cent.); and 'decidedly retarded' (below 80 per cent.).

Leaving out the results in the 'dialysis' stage of beef digested in presence of coffee, on account of the above-mentioned leakage, there remain 17 results in Table E for comparison with a similar number in Tables F and G. The table on the page opposite shows a close correspondence between the results with the two fluids.

| (a) In the same Class in both Tables. | | |
|---------------------------------------|----------------|-------------------------------------|
| Peptic Stage. | Egg, Coffee. | Unaffected (E and G). |
| | Bread, Coffee. | Unaffected (E and G). |
| Tryptic Stage. | Egg, Tea. | Retarded (E and G). |
| | Beef, Tea. | Retarded (E and G). |
| | Bread, Tea. | Retarded and minus (E and F). |
| | Egg, Coffee. | Unaffected (E and G). |
| | Beef, Coffee. | Retarded (E and G). |
| Dialysis Stage. | Bread, Coffee. | Minus (E and F). |
| | Bread, Tea. | Minus (E and F). |
| | Bread, Coffee. | Minus (E and F). |
| (b) In adjoining Classes. | | |
| Peptic Stage. | Egg, Tea. | Slightly retarded (E). ¹ |
| | | Unaffected (G). |
| | Beef, Tea. | Slightly retarded (E). |
| | | Retarded (G). |
| Dialysis Stage. | Egg, Coffee. | Assisted (E). |
| | | Unaffected (G). |
| | Beef, Coffee. | Retarded (E). |
| | | Slightly retarded (G). ² |
| (c) In widely separated Classes. | | |
| Peptic Stage. | Bread, Tea. | Retarded (E). |
| | | Assisted (G). |
| | Coffee, Beef. | Assisted (E). |
| | | Slightly retarded (G). |
| Dialysis Stage. | Egg, Tea. | Unaffected (E). |
| | | Retarded (G). |

The percentages in Tables E and G may be examined together to ascertain what are the effects of the beverages on digestion. Taking the very broadest basis for a calculation, viz., an average of all the percentage 'Total' results in both tables, the following figures are obtained:—Water, 100 per cent. ; tea, 91·00 per cent. ; coffee, 97·25 per cent. ; cocoa, 56·79 per cent.

That is to say, the united results of very numerous experiments go to show that coffee does not retard the digestion of foods, that tea does so slightly, and cocoa very decidedly.

¹ Only ·58 per cent. below 'unaffected' class.

² Only 1·13 per cent. above 'decidedly retarded' class.

| | Tea. | Coffee. | Cocoa. |
|---------------------------|--|---|---|
| <i>Peptic Digestion.</i> | | | |
| Assisted. | Yelk of Egg, Ham, Bread (Table G), Potato. | Roast Beef (Table E), Yelk of Egg, Ham, Fish, Potato. | Bread, Potato. |
| Unaffected. | White of Egg (Table G). | White of Egg, Bread (Tables E and G). | None. |
| Slightly retarded. | White of Egg (Table E), Roast Beef (Table E), Fish. | Roast Beef (Table G), Fowl. | White of Egg, Ham. |
| Decidedly retarded. | Bread (Table E), Roast Beef (Table G), Salt Beef, Mutton and Fowl. | Salt Beef, Mutton. | Yelk of Egg, Roast Beef, Salt Beef, Mutton, Fish. |
| <i>Tryptic Digestion.</i> | | | |
| Assisted. | Ham, Mutton. | Yelk of Egg, Ham, Fowl. | None. |
| Unaffected. | Yelk of Egg. | White of Egg (Tables E and G), Fish. | None. |
| Slightly retarded. | Salt Beef. | Salt Beef. | Yelk of Egg. |
| Decidedly retarded. | Egg, Roast Beef, Bread (Table E), White of Egg, Roast Beef (Table G), Fowl and Fish. | Roast Beef (Tables E and G), Mutton. | All Meats except Yelk of Egg. |
| <i>Dialysis.</i> | | | |
| Assisted. | Ham. | White of Egg (Table E), Ham and Fowl. | None. |
| Unaffected. | White of Egg (Table E). | White of Egg (Table G), Yelk of Egg, Salt Beef, Fish. | None. |
| Slightly retarded. | Yelk of Egg, Salt Beef, Mutton. | Roast Beef (Table G). | None. |
| Decidedly retarded. | White of Egg (Table G), Roast Beef (Table G), Fowl and Fish. | Roast Beef (Table E), Mutton. | Every Meat used. |

If, next, instead of thus broadly averaging the results, the 'Totals' for each meat are distributed into the four classes, the following results come out:—

'Assisted': by tea, ham; by coffee, white of egg (Table E), yelk of egg, ham, fowl, and fish; by cocoa, none.

'Unaffected': by tea, none; by coffee, white of egg (Table G); by cocoa, none.

'Slightly retarded': by tea, white of egg (Tables E and G), yelk of egg, salt beef, and mutton; by coffee, roast beef (Table G) and salt beef; by cocoa, none.

'Decidedly retarded'; by tea, roast beef (Table G), fowl, and fish; by coffee, roast beef (Table E) and mutton; by cocoa, every meat with which it was tried.

The only meat 'assisted' by both tea and coffee is ham; 'assisted' by coffee and 'slightly' retarded by tea are white and yelk of egg; slightly retarded by both tea and coffee is salt beef.

There are two or three meats which appear irregularly in widely separated classes with tea and coffee, such as roast beef, fowl, and fish; in some of their higher results there is reason to believe that leakage had taken place, *e.g.*, the 'tryptic' and 'dialysis' stage of the digestion of fowl in presence of coffee; with cocoa there are no such irregularities, all the meats with it giving results in the lowest class.

Thus, as originally shown in the first paper of this series, eggs and salted meats have more than custom to justify the position they usually hold on our breakfast tables.

Considering next the results in the three stages of the experiments, the tabular form will, for conciseness, be again resorted to.

The first thing to be noted in the table is that the vegetable albuminoids, though giving minus figures in the 'tryptic' and 'dialysis' stages, and therefore not appearing in the totals, appear to be less unfavourably affected in peptic digestion than those of animal origin: thus tea and cocoa (Table G) assist the digestion of bread and potato, and coffee assists that of potato. Coffee (Tables E and G) has no effect on the digestion of bread, while tea (Table E) appears to retard it. This is the solitary instance in which the peptic digestion of vegetable albuminoids is retarded by any infused beverage, and may easily be an error,

as the amounts dealt with are very small.¹ The other results with tea and coffee in the 'peptic' stage are practically the same as the 'Totals,' with the apparently inexplicable exception of salt beef, which in this stage falls into the 'decidedly retarded' class with both beverages; it rises, however, a step in the 'tryptic' stage, and maintains or improves its position in the 'dialysis.' In the 'peptic' stage, with tea it just misses the higher class by .67 per cent., and in the 'tryptic' by 1.04 per cent.

Ham is the only meat which in all stages, and with both tea and coffee, falls into the 'assisted' group. Of the egg experiments with coffee as the beverage, in no case is one found lower than the 'unaffected' group. Tryptic digestion of white of egg is retarded more than 20 per cent. by tea ('tryptic' and 'dialysis' stages; all the other results of egg with tea are in the three higher classes.²

The irregular results are similar to those in the 'Totals,' viz., roast beef, fowl, and fish, these appearing sometimes in higher, sometimes in lower classes. In the 'tryptic' stage with tea, mutton gets into the assisted class, but this, being its solitary appearance above 95 per cent., may be set down to an experimental error.

With cocoa, except bread and potato, no foods ever rise above the 'slightly' retarded class, and only three attain that, viz., white of egg and ham in the 'peptic' stage, and yolk of egg in the 'tryptic.'

In comparing the effects of the beverages on peptic and tryptic digestion it will be well to look only at the 'peptic' and 'dialysis' figures respectively, for, as pointed out in vol. xxi, the 'tryptic' results must chiefly consist of peptic peptones. On examining the table, p. 478, it is found that ham is alike 'assisted' in the peptic and dialysis stages by tea and coffee, that white of egg (Table G) is in both stages 'unaffected' by

¹ Penyoldt (*Deutsch. Arch. für klin. Med.*, li. p. 535) showed that tea facilitated the disappearance of bread from the stomach. In the former paper (vol. xx.) it was shown that tea assisted the peptic digestion of gluten, and coffee only slightly retarded it, but both decidedly retarded its tryptic digestion.

² The results with egg agree closely with those of Herzen in his experiments on a gastrotomised patient, in which he found that coffee assisted and tea did not retard the digestion of white of egg (*Revue med. de la Suisse Romande*, 1885).

coffee, and roast beef (Table G) only 'slightly retarded,' while in both stages tea 'decidedly retards' the digestion of roast beef (Table G), and of fowl. Coffee 'decidedly retards' that of mutton, and cocoa of all meats except white of egg. Thus of the results recorded in Tables E and G, and analysed in the table, p. 478, three with tea as the beverage show no difference between peptic and tryptic digestion, four in the case of coffee, and five in the case of cocoa; it may, however, be noted that of these twelve results with similar action both on peptic and tryptic digestion, seven are similar, because they are in the lowest possible class.

Of cases in which peptic digestion is less affected than tryptic, there are three with tea, yolk and white of egg, and fish; three with coffee, roast beef (Table E), yolk of egg, and fish; and two with cocoa, white of egg and ham.

Of the reverse—*i.e.*, cases in which tryptic digestion is less affected than peptic—there are, again, three with tea, white of egg (Table E), salt beef, and mutton; three with coffee, white of egg (Table E), salt beef, and fowl; and with cocoa, none.

Thus, as it happens that a number of meats show no difference between their peptic and tryptic digestibilities in presence of these beverages, and that in the cases of tea and coffee, a number are more unfavourably affected in peptic than in tryptic digestion, and an equal number less unfavourably by these beverages, the conclusion may fairly be drawn that, as far as the conditions of these experiments with Benger's Liquor Pancreaticus are concerned, the action of the beverages is much the same on tryptic as on peptic digestion.

Those cases in which peptic is less unfavourably affected than tryptic digestion are chiefly those of the 'breakfast' meats, *viz.*, for tea, yolk and white of egg; for coffee, yolk of egg; and for cocoa, white of egg and ham; and, as noted above, the cases where peptic and tryptic digestion are similarly affected are chiefly those of meats whose digestion is decidedly retarded in both stages, but the 'dialysis' figures with personally prepared pancreatic fluid (Table E) of the digestion of white of egg in presence of tea and of coffee show that this was not retarded by the beverages. The 'dialysis' figure of the digestion of beef in the presence of coffee in the same table shows, on the other hand, considerable retardation.

As to the action, then, of the beverages on tryptic digestion, the conclusion seems to be that the action of Benger's Liquor Pancreaticus is retarded by infused beverages very generally, and even in cases where the action of Liquor Pepticus is assisted, but that the solution prepared from fresh Kühne's Pancreas Powder is not so much retarded in its action. This latter result agrees with that found by Sir W. Roberts.¹

The results of the experiments with the less important beverages may be arranged in the same groups as the others, and will be found in Tables H, I, and for rapid inspection in the table on opposite page, in which the meats instead of the beverages are at the heads of the columns, reversing the arrangement in the former tabular statement. Analysing the 'Total' results first, of the teas, green tea does not appear to affect digestion unfavourably, neither does the cheap congou nor coca; compressed tea and maté do little harm. Of the coffees, that of 15 per cent. strength decidedly retards instead of assisting digestion, as the 3 per cent. coffee does, thus confirming the results of Sir W. Roberts.² The addition of chicory has the same effect, but coffee made in the Arab manner has little retarding action.

Of the cocoas, chocolate and guarana assist digestion, cocoatina and khola chocolate retard it decidedly, but 'miserables' only slightly. All these apply to the digestion of white of egg, but a few experiments with beef and with bread were also performed. Cocoatina and cocoa nibs retard the digestion of beef, and cocoatina, cocoa nibs, and Arab coffee gave minus results with bread in the 'tryptic' and 'dialysis' stages (Table H). The results with the less important beverages are derived from one experiment, and therefore cannot be subjected to a too closely critical examination of the individual stages; still, a few points may be noted.

Cocoatina does not retard the peptic digestion of bread: coffee with chicory does so slightly, and cocoa nibs decidedly; the peptic digestion of roast beef is also decidedly retarded by cocoa nibs and cocoatina. In the results with white of egg, digestion is assisted in all its stages by the cheap congou tea, showing that from this point of view cheapness does not mean

¹ *Dietetics and Dyspepsia*, p. 67.

² *Ibid.*, p. 47.

| | White of Egg. | Beef. | Bread. |
|---------------------------|--|------------------------|----------------------|
| <i>Peptic Digestion.</i> | | | |
| Assisted. | Green Tea, Tea with Soda, Cheap Congou, Compressed Tea, Coca, Maté, Cocoa Nibs, Guarana, Chocolate, Khola. | None. | None. |
| Unaffected. | Cocoatina, Miserables. | None. | Cocoatina. |
| Retarded slightly. | Arab Coffee. | None. | Coffee with Chicory. |
| Retarded decidedly. | Coffee with Chicory, Coffee 15 per cent. | Cocoa Nibs, Cocoatina. | Cocoa Nibs. |
| <i>Tryptic Digestion.</i> | | | |
| Assisted. | Coffee 15 per cent., Cheap Congou, Chocolate. | None. | None. |
| Unaffected. | Maté and Guarana. | Cocoatina. | None. |
| Retarded slightly. | Coca, Cocoatina, Miserables. | Cocoa Nibs. | None. |
| Retarded decidedly. | Green Tea, Tea with Soda, Compressed Tea, Arab Coffee, Coffee with Chicory, Cocoa Nibs, Khola. | None. | None. |
| <i>Dialysis.</i> | | | |
| Assisted. | Green Tea, Cheap Congou, Coca, Guarana, Chocolate. | None. | None. |
| Unaffected. | Arab Coffee. | None. | None. |
| Retarded slightly. | Compressed Tea, Maté, Arab Coffee, Khola. | None. | None. |
| Retarded decidedly. | Tea with Soda, Coffee with Chicory, Cocoa Nibs, Cocoatina, Miserables, Coffee 15 per cent. | Cocoatina, Cocoa Nibs. | None. |
| <i>Totals.</i> | | | |
| Assisted. | Green Tea, Cheap Congou, Coca, Guarana, Chocolate. | None. | None. |
| Unaffected. | None. | None. | None. |
| Retarded slightly. | Compressed Tea, Maté, Arab Coffee, Miserables. | None. | None. |
| Retarded decidedly. | Tea with Soda, Coffee with Chicory, Coffee 15 per cent., Cocoa Nibs, Cocoatina, Khola. | Cocoa Nibs, Cocoatina. | None. |

unwholesomeness. Mat   does not greatly retard in any stage, and assists in the peptic.

Chocolate alone of the cocoa beverages assists digestion in all these stages. Cocolatina does not affect peptic digestion, but retards tryptic, being in the lowest class in the 'dialysis' stage. 15 per cent. coffee assists digestion in the 'tryptic' stage, but decidedly retards it in the other two; Arab coffee also decidedly retards in the 'tryptic' and 'dialysis' stages, but slightly in the 'peptic'; but coffee with chicory is always in the lowest class. Guarana in all three stages either assists or does not retard digestion, and khola chocolate, while retarding in the 'tryptic' and 'dialysis' stages, assists in the 'peptic,' thus agreeing with the results of Monnet.¹

As a whole, it may be said that the teas and cocoas follow more or less the rules which might have been deduced from the behaviour of their typical examples, the teas assisting the peptic digestion of white of egg, but retarding the tryptic; and the cocoas, though many of them assist in the 'peptic' stage, very decidedly retarding in the other two.

The coffees, however, diverge from their typical example, all the modifications which were subjected to experiment retarding digestion more or less in nearly all the stages.

There is another point which came out in these investigations, to which attention may be drawn here, viz., the effects of the typical beverages on the consumption of acid during the process of peptonisation. This was detected when neutralising the contents of the dialysers at the end of the 'peptic' stage; 10 per cent. sodic carbonate solution being used for the purpose, and the amount required noted in each case. The average amounts in all the experiments with water and the three typical beverages were—with water, 1.19 c.c.; with tea, 1.30 c.c.; with coffee, 1.28 c.c.; and with cocoa, 1.40 c.c. These, if stated as percentages, give with water, 100; with tea, 109.2; with coffee, 197.5; and with cocoa, 117.6;—showing that 9 per cent. less acid is consumed in digestion in presence of tea, 7.5 in presence of coffee, and 17.6 in presence of cocoa. These figures, then, are confirmatory of the general average of the 'Totals,' p. 477, in which all the three beverages are shown to retard digestion.

¹ *Th  se de Paris*, 1884, Monnet.

cocoa the most and coffee the least; for, as is well known, acid is consumed in the process of peptonisation, and anything which retards the process must reduce the consumption of acid.

The figures on p. 477 above referred to, are worthy of a little further consideration: they are the averages of ten sets of 'Total' results in Tables E and G, each set being derived from one or more experiments. Considering them in the light of some statements made in the last few pages, it is seen that they are unduly favourable to the beverages, for they are derived from a number of experiments on meats whose digestion has been shown to be assisted by these beverages, and from an equal number whose digestion is generally retarded, but which give here and there results which, though regarded with suspicion as being possibly experimental errors—*e.g.*, that with fowl digested in presence of coffee (Table G)—yet tend to show that the meat is occasionally assisted in digestion by the beverage.

If, then, averages be taken of the results with meats in the first group, viz., white and yolk of egg, ham, and salt beef, the figures run,—in presence of water, 100 per cent.; of tea, 94·11 per cent.; of coffee, 106·78 per cent.; and of cocoa, 58·89 per cent.: while in the second group, viz., roast beef, mutton, fowl, and fish, they run,—in presence of tea, 69·76 per cent.; of coffee, 87·90 per cent.; and of cocoa, 53·98 per cent.;—showing in the cases of tea and coffee the decidedly more advantageous position of the 'breakfast' meats, while in the case of cocoa there is little to choose between the two groups.

Summary of above Experiments.

(1) Infused beverages, as a rule, retard peptic, and possibly tryptic, digestion of albuminoid food stuffs, as compared with the rate of digestion with water as the beverage.

(2) There are certain exceptions to the above in the cases of the teas and coffees; very few in that of the cocoas: the food stuffs excepted are,—for the teas and coffees, egg and salted meats; and for all three beverages, the gluten of bread and other vegetable albuminoids.

When these meats are retarded in digestion, the delay is usually less than with other meats.

(3) The consumption of hydrochloric acid in peptonisation is reduced by all three beverages; most by cocoa, and least by coffee.

Next come to be considered the possible causes of these actions of the beverages. In the first paper of this series (vol. xviii. p. 26 *et seq.*) they were enumerated under eight heads, and examined by the processes there adopted, and as far as they affected peptic digestion. These possible causes and two others are here re-examined, both as to their actions on peptic and tryptic digestion.

The first possible cause of the retarding action of the beverages is, that ferment may be carried down by the precipitate formed on mixture of the beverage and digestive fluid, and may fail to be completely redissolved during the progress of digestion. This is a known property of these ferments.¹

Coffee does not cause this precipitate, and therefore this cause can only apply to tea and cocoa.

The experiment was tried as follows:—tea was mixed with the peptic fluid in the proportions of 1 part of tea to 2 parts of fluid and the mixture filtered, 30 c.c. of the filtrate were used in a digestion experiment, otherwise performed exactly as described on p. 472, the only difference from a regular experiment being that the digestive mixture was free from precipitate, and therefore from any pepsin which that precipitate had entangled.

A 'Factor' experiment was performed, with the result shown in Table J, from which it will be seen, on comparison with Table B, that the nitrogenous matters dialysed sustained no loss by the removal of the precipitate, but rather gained (·0078 Table J, ·0069 Table B), and therefore it may fairly be concluded that the precipitate yielded nothing to digestion. It must be said that the experiment on this point related in vol. xviii. led to an opposite conclusion.

Turning to the results of the digestion of white of egg with this same digestive mixture (Table K), they are found to be opposed to the effectiveness of this cause, for the 'total' digestive power of both peptic and tryptic digestive fluids appears to

¹ *Handbook for Phys. Lab.*, Sanderson, p. 521.

be raised by the removal of the precipitate from 80·66 per cent. (Table G) to 92·09 per cent. (Table K). The efficiency of this cause, therefore, seems more than doubtful, although in the former paper the experiments led to the opposite conclusion.

The two next possible causes may be considered together: they are, (2) the coagulation, by the tannic acid of the beverages, of any albuminoids not already coagulated by the heat of cooking; and (3) the tanning and contraction, by the same body, of the gelatinous bands in the meat, caused by the cooking of the perimiscium. This contraction would retard digestion by preventing the swelling of the meat, in the same way as a piece of thread firmly wrapped round some fibrin prevents its digestion.¹

The following table shows the action of the different tannic acids of the beverages in precipitating various albuminoids.

| Tannic Acid. | Egg Albumen. | Serum Albumen. | Syntonin. | Alkali Albumen. | Gelatin. |
|--------------|---------------------|----------------|--------------|-----------------|---------------------|
| Of Tea, . | Precipitate. | Precipitate. | Precipitate. | Precipitate. | Slight precipitate. |
| „ Coffee, . | Slight precipitate. | Precipitate. | None. | None. | None. |
| „ Cocoa, . | Slight precipitate. | Precipitate. | Precipitate. | ... | None. |

Considerable evidence in favour of the action of both these causes can be drawn from experiments already described.

Thus, in the chief set of experiments, it was found that coffee had, as a rule, a less retarding action on digestion than tea, and it is seen from the above table that caffee-tannic acid acts as a much less astringent body than that of tea, which is the same as that of oak bark. Further, from Payen's analyses, tea contains nearly 2·5 times as much tannic acid as coffee.

Among the bodies least influenced by tea in its digestion is white of egg, an albumen already fully coagulated by boiling, and, further, one in which there is no gelatinous residue of a perimiscium to be coagulated by the tannic acid. There is thus nothing in the white of egg to be unfavourably influenced

¹ *Handbook for Phys. Lab.*, Sanderson, p. 488.

by either of these causes, and hence its digestion is little retarded.

Again, the fact that salted meats are little retarded in digestion by tea is in favour of the efficiency of these causes, for it is well known that a solution of salt is an excellent solvent of the collagenous matter of white fibrous tissue, and it has been used for this purpose by microscopical observers to facilitate the teasing out of preparations. The perimiscium being thus largely dissolved out of the salt meat, cannot leave gelatinous bands to contract, and retard its digestion.

Sir W. Roberts attributes one-half of the retarding power of tea to its tannic acid¹: from these experiments, it appears as if more might be laid to its charge. Experiments on the action of these possible causes were performed as follows,—three equal quantities of the same tea, the quantity being the same as in the regular experiments, were infused; the first, with the usual quantity of water for 2 minutes²; the second, for the usual 20 minutes with a part of the water, and in the rest gelatine was dissolved in the proportion of four parts to every estimated part of tannic acid in the tea, the gelatine solution was added to the infusion, and the precipitate partly removed by filtering through linen, the tannic acid being thus rendered inactive; the third quantity was boiled for five minutes with the usual quantity of water, to make a thorough extract of the leaves.

The 'Factors' of these modified beverages are given in Table L, and from an interesting group, showing how closely the results of the processes of digestion and estimation agree among themselves: the thorough extracting of the tea by boiling causes a little more nitrogenous matter to be yielded to digestion, and the addition of the gelatine also gives a slightly increased result, probably derived from extractives present in the gelatine. It

¹ *Dietetics and Dyspepsia*, p. 59. Dr M'Kechie of Colombo (*Lancet*, 1895, vol. ii. p. 998) considers, from experiments in vitrio, and on the monkey, that tannic acid is not the active agent in the retarding action of tea, which he states increases the time of digestion 18 per cent. He notes no difference between tea infused 5 minutes, 20 minutes, or tea from which the tannin is removed by gelatine.

² Sir W. Roberts makes light of this precaution (*ibid.*, pp. 30 and 47), and a *Lancet* 'Commission' (vol. ii., 1893, p. 478) also shows that infusion for 15 minutes instead of 5 only increases the tannic acid from 89 to 92.

was noted that all three gave precipitates on mixing with the peptic fluid, but that these were very slight with the 'two minutes' and 'tannin free' tea, so that in the latter case it might only have consisted of the imperfectly removed tannate of gelatine.

The results of the digestion of roast beef in presence of these beverages are given in Table M, where the 'totals' show that the removal or reduction of the tannic acid reverses the action of the tea on digestion, and that its concentration in the boiled tea causes the retarding action to be kept up.

The individual results in the various stages are rather different, for all three modifications appear to assist peptic digestion, and 'tannin free' tea assists in all three stages, while 'two minutes' tea only retards in the 'tryptic' stage, but boiled tea only assists slightly (only rising 2·3 per cent. above the unaffected group in the peptic stage, and thereafter considerably retards digestion.

These experiments and the deductions made above from those recorded in Table G seem to justify the assertion that (2) the coagulation by the tannic acid of the beverage of the albuminoids of the meats which have escaped coagulation by cooking, and (3) the tanning of gelatinous bands in the meat, are effective causes of the retardation of the digestion of meats by tea and cocoa. The fourth possible cause—retardation by the action of the volatile oils of the beverages—was not re-examined: this action was shown (vol. xviii. p. 28) to be small and doubtful.

The fifth possible cause—the action of the alkaloids—was also not re-examined: it was shown (vol. xviii. pp. 28 and 37) to be slight, and in the case of coffee, at any rate, to act in the direction of assisting digestion, so that the alkaloid may be the active agent where digestion is expedited.

The sixth possible cause is the precipitation of the syntonin, alkali albumen, and peptones, as formed by the tannic acid of the beverages. No further experiments were performed on this point, but that described under the second and third causes is partly applicable to this.

It is known that tannic acid precipitates peptones, and from the Table, p. 486, it is seen that that of tea and cocoa precipitates syntonin, and that of tea, alkali albumen. It is therefore evident

that so long as the acid remains in solution in the fluids of the stomach and duodenum, so long will these three bodies be precipitated as quickly as they are formed. This possible cause may therefore be taken as efficient.

The seventh possible cause is, that the accumulation of peptones derived from the digestion of beverages (such as the cocoas) containing much albuminoid would hinder the digestion of the albuminoids of the meat: this only applied to the experiments under the conditions of the first series, and not to these later experiments, or to digestion in the stomach, in which cases dialysis or absorption removes the peptones as quickly as formed.

The eighth possible cause, viz., the covering up and clogging of the food by the suspended solids of the cocoas, of course only applies to these beverages.

Experiments were performed on this point, with the results shown in Tables J and K. The 'Factor' experiments with filtered cocoa (Table J) shows that the removal of the suspended solids allowed freer dialysis of the crystalloid nitrogenous principles, and the 'total' result with filtered cocoa is greater than that with water alone, thus differing from that with unfiltered cocoa in Table B.

But the 'total' results of the digestion of white of egg in presence of filtered cocoa show that the removal of its suspended solids only slightly reduced its retarding power, the percentage result being 86.08 compared with 77.11 with unfiltered cocoa in Table G. If the individual stages are examined, however, it is found that in the peptic stage filtered cocoa assists the digestion of white of egg, while in the 'tryptic' and 'dialysis' stages it retards it. The former result confirms that found in the former paper, vol. xviii. p. 31, and this is supported by the results in Table I, where it is seen that cocoa nibs infusion, which is free from suspended matters, assists digestion in the 'peptic' stage, though retarding it in the 'tryptic' and 'dialysis'; and cocoatina, which has less suspended matter than Epps's cocoa, does not retard in the 'peptic' stage, though it does in the 'tryptic' and 'dialysis.' Chocolate and khola paste differ in action from the above, but their composition is too complex to allow deductions to be made from their action.

It is probable that the greater mixing action of the muscular movements of the stomach will prevent this action of the suspended matters, which the stirring arrangements used in these experiments were not sufficiently powerful to effect, but it appears sufficiently proved that under the conditions of the experiments the clogging action of the suspended matters of the cocoas had a great effect in retarding peptic digestion, which might otherwise have been assisted by these beverages, but that other actions were at work in retarding tryptic digestion.

The ninth possible cause is the action of the beverages and of tea in particular in retarding the conversion of syntonin into peptone.

Two experiments were performed on the model of the 'peptic' stage with white of egg and personally prepared gastric fluid in presence (*a*) of water, of tea, and of coffee respectively.

After 6 hours' digestion the contents of the dialysers were rendered alkaline to the extent of 1 per cent. with soda carbonate which redissolved the syntonin, at first precipitated, the solution was filtered to remove suspended insoluble matters, and the dialysers and filters washed, and the washings filtered and mixed with the filtrate; the mixed filtrates were neutralised with dilute hydrochloric acid, and the precipitated syntonin collected on weighed filters, washed, dried, and weighed, with the following results: syntonin present with water as the beverage, .098 gm.; with tea, .132 gm.; with coffee, .106 gm.

In the second (*b*) experiment, which was performed on the same lines, the beverages were water, water with the tannic acid of 10 c.c. of tea, water with the alkaloid of the same amount, and water with the volatile oil: the results were, syntonin formed in presence of water, .059 gm.; in presence of water and tannic acid, .113 gm.; of alkaloid, .080 gm.; and of volatile oil, .082 gm.

It is evident, therefore, that this cause is effective in the retarding action of tea on peptic digestion, but not with coffee; and further, that the tannic acid is the active agent, though the alkaloid and volatile oil may assist. It must be understood that this action is quite different from that discussed under cause 6, viz., the precipitation of the syntonin as formed: the syntonin in this case remains in solution, and is simply prevented from passing into the state of peptone.

The tenth possible cause is the action of the beverages on dialysis, which appears *a priori* possible from the following considerations.

Traube¹ showed that a membrane of tannate of gelatine, used as a dialyser, allowed the passage of baric nitrate (molecular weight 130), but would not allow that of potassic ferrocyanide (molecular weight 211·4). Hæmoglobin, though a crystalloid body, will not dialyse, on account of its high molecular weight; peptones also pass with great difficulty through parchment paper, and thus their dialysis would be easily affected by the presence of other crystalloids in solution with them.

Experiments were made, with the results shown in Table N, by the following process. Sufficient solution of peptone in ·2 per cent. hydrochloric acid was made to supply all the experiments: thus, though the quantity of peptone was unknown, the strength of the solution was the same in each experiment.

Twenty c.c. were placed in a dialyser arranged as in the regular process of experiment, and to it 10 c.c. of beverage were added. When tea was the beverage, a precipitate was produced on adding it to the peptone solution.

Dialysis took place into 120 c.c. of ·2 per cent. hydrochloric acid solution, and lasted for six hours. At the end of this time the dialysate was removed, and the content of the dialysers were made alkaline to the extent of 1 per cent. of sodic carbonate, dialysis was resumed in 140 c.c. of distilled water, and continued for 24 hours, the apparatus being first heated, until the temperature in the dialysers attained 80° C.; the first and third stages of an ordinary experiment being thus imitated. The beverages used were water, the three typical infused beverages, and, fifthly, a saturated solution of sugar.

Examining the percentage results in Table N, it is seen that tea and coffee in both stages increased the amount of peptone dialysed, that cocoa was practically without effect, and that the syrup greatly reduced the amount in the first stage, but increased it in the second.

Its action in the first stage, no doubt, resulted from the more mobile—that is, more crystalloid—molecules of the sugar crowding the sluggish peptone molecules away from the pores of the

¹ *Centralblatt für die Med. Wiss.*, 1886, p. 114.

parchment paper; probably, also, the molecules of sugar being smaller than those of peptone, could pass through openings impassable to the latter.

By thus taking advantage of their numbers and mobility in the 6 hours stage, so much sugar would pass away that early in the 24 hours stage an equilibrium of sugar inside and outside the dialyser would be produced, and sugar dialysis would cease; then the peptones, kept back in the first stage, and therefore present in the syrup dialyser in greater amount at this period than in the one in which they were mixed with water only, could and did dialyse in larger quantity than in this stage of the water experiment. That this is the correct explanation is seen in reference to the actual results; for while in both stages, with water as the beverage, .0033 grm. of nitrogen passed through the dialyser, when syrup was used, .0034 grm., or substantially the same amount, was dialysed. Thus, strong syrup retards the dialysis of peptones while it is strong; but if the sugar lost by dialysis is not renewed, a stage will be reached when the peptones will be able to reassert themselves, and if time is allowed, will dialyse in as large quantity as if mere water had been mixed with them.

The action in the case of tea and coffee, however, is to accelerate dialysis, not to retard it. If it be objected that the figures in Table N, under the heads of these beverages, are deceptive, and depend on the nitrogen derived from the beverages themselves, a sufficient answer is found in Table C, when the dialysable nitrogen of the beverages is recorded, and it is seen that with tea and coffee, if the whole dialysable nitrogen they contain were subtracted from the result in either stage of this experiment, the change would be only one of degree, and not of kind.

Such treatment, however, would be manifestly unfair, for the results in Table C are calculated for the whole dialysable nitrogen of 10 c.c. of the beverage, and at the end of such an experiment as described above some of this would still remain in the dialyser.

Further, the tea precipitated some of the peptone, which, if it had remained in solution, would have increased the amount dialysed.

It is therefore evident that tea and coffee by some means facilitate the dialysis of peptones through parchment paper. The action of cocoa may be explained as a balancing of opposing forces, some constituents of the beverage trying to force more peptone to dialyse, and the sugar, on the other hand, retarding its passage through the parchment paper. It is to this action of the beverage that the smallness of the 'Factor' results with the cocoas referred to on p. 474 seems attributable: a weak solution of dialysable nitrogenous matter had its dialysis opposed by a syrupy and starchy liquid.

This action also throws some light on the reversal of the action of coffee on digestion by the addition of chicory, the principal element introduced into the beverage by the latter substance being sugar. Further, the minus results in the 'tryptic' and 'dialysis' stages with bread (Tables E and F) are probably attributable to the same cause: bread contains but little albuminoid, and that easily digested; it would be peptonised in the first stage, and with tea or coffee its dialysis is accelerated. In the 'tryptic' stage the digestion of the starch commences, and the fluid, coming to contain much glucose and little peptone, a struggle for the molecular openings in the dialyser is set up, and the peptones are crowded away by glucose, as also are the nitrogenous crystalloids of the beverage and digestive fluids, with the result that a minus figure appears in the table in this and the next stage.

It therefore appears that tea and coffee accelerate the dialysis of peptones, but that cocoa has little effect. Whether this action can take place in the stomach is doubtful: it would require a very large dose of sugar to make a strong enough syrup to cause any retardation of dialysis from that organ, but the accelerating actions of the beverages may take place even there.

The indications as to the causes of the actions of infused beverages on digestion may be *summarised* as follows:—

I. It does not appear that the precipitate produced by tea and cocoa in the digestive fluid carries down with it any ferment, so as to render this inactive: this is opposed to the conclusion arrived at in the first paper of the series, and must be considered doubtful.

II. and III. The tannic acid of the tea and cocoa appears to

retard the digestion of meat by coagulating albuminoids which have escaped the action of cooking, and by tanning the perimiscial gelatine.

IV. The action of the volatile oil was not re-examined: it is small and doubtful.

V. The action of the alkaloid was also not re-examined, and, if anything, favours digestion, especially in the case of coffee.

VI. The tannic acid of tea and cocoa further retards digestion, by precipitating the syntonin, alkali albumen, and peptones, as formed.

VII. The accumulation of peptones was not an efficient retarding cause in these experiments.

VIII. The clogging action of the suspended solids has a real action in hindering digestion under the conditions of these experiments.

IX. Both tea and coffee retard the conversion of syntonin into peptone, the most active principle in this direction being the tannic acid.

X. Both tea and coffee accelerate the dialysis of peptones, but cocoa has little effect.

Attention may next be turned to the amylolytic action of the pancreatic fluid. A number of experiments were performed to ascertain the effect of infused beverages on the pancreatic digestion of bread and potato: they were performed both with the personally prepared digestive fluid above described, and with the Bengel preparation. Up to the end of the digestive and dialysis stages, the process followed was exactly that described on p. 472: the dialysates from the tryptic and dialysis stages were mixed, and evaporated to small bulk on a water bath, the peptones were removed by precipitation with alcohol, this was removed by distillation, and the sugar in the residue estimated by Fehling's process. 'Factor' experiments were made with all the beverages, but only three contained enough carbohydrate to make these necessary, these being beverages of the cocoa class, and the 'Factors' being shown in Table O, from which it is seen that Epps's cocoa and chocolate contained about equal quantities of carbohydrate, and khola chocolate only about one-fourth as much.

The actual and percentage results of the digestion of bread

by the personally prepared digestive fluid are shown in Table P, and those of the digestion of bread and of potato by the Benger preparations in Table Q.

As experiments with bread appear in both tables, these may be first compared as a test of the value of the results with the Benger preparation, and between the two a serious discrepancy is found, for digestion by the personally prepared fluid is seen not to suffer any interference from the presence of the beverages, while digestion by the Benger preparation is retarded slightly by coffee and cocoa, decidedly by tea. Therefore the effect of beverages on the digestion of starch by Benger's Liquor Pancreaticus cannot be taken as a true indication of their effect on its digestion by more simply prepared digestive fluids, or on digestion in the small intestine.

From the single experiment recorded in Table P, it would appear that pancreatic digestion is unaffected by infused beverages.

The results in Table Q have only a pharmacological interest as showing the effects produced by the beverages on the digestion by the Benger preparation, and they appear to show that these beverages retarded the digestion of the starch of bread, but assisted that of potato. From Table R it is seen that the 'modified' teas all retarded the digestion of bread, 'tannin free' tea most actively, thus making it probable that some other principle than the tannic acid is here active.

The CONCLUSIONS which may be drawn from this part of the paper are few and short.

I. In the small intestine, it is probable that infused beverages have no effect on the digestion of starch.

II. Digestion of bread by Benger's Liquor Pancreaticus, is retarded by the three typical infused beverages, that of potato accelerated by tea and coffee.

DEDUCTIONS.

In the matter of the use of infused beverages, three classes of habits may be distinguished.

The first may be called the continental habit, as it is the one

followed by most of the great European nations,—Russia, Spain, and Portugal being the chief exceptions.

By other continental nations, infused beverages are hardly taken except at the 'first breakfast' (which consists of a cup of coffee and a roll), and the after-dinner cup of coffee.

In Spain and Portugal, chocolate largely takes the place of coffee, but otherwise the customs appear to be the same. Tea is regarded by all these nations rather as a medicinal draught than as a beverage.

In Britain, on the other hand, tea is the most largely used of all beverages, and has been so since its introduction. The use of coffee is steadily decreasing, and that of cocoa slowly increasing.

The use of tea in England is regulated by the other two of the above-mentioned habits; and into which class any particular person will fall, is chiefly a question of wealth.

The richer classes use infused beverages, usually tea or coffee, at breakfast, afternoon tea, and a cup after dinner; the poorer, on the other hand, use almost always tea, and take it at every meal, and the women often between meals also. In this latter class, also, the Russians should find their place, the samovar being an ever-boiling institution in that country.

The three classes of consumers of infused beverages then are :—

- (1) The continental class, chiefly drinking coffee,—drinking it accompanied only by vegetable food, except the after-dinner cup;
- (2) The richer British class, drinking either tea or coffee at breakfast, tea at afternoon tea, and coffee after dinner; accompanying the breakfast beverage with vegetable food and eggs, or salted meats, and the afternoon tea with vegetable food only; and
- (3) The poor British class and the Russians, drinking tea almost exclusively, and drinking it at every meal, whether of animal or vegetable food.

Now, of these three classes, the first is undoubtedly the wisest: it has been seen in Tables E and G that bread, the typical vegetable food, is unaffected, or assisted in its peptic digestion, by tea, coffee, and cocoa alike.

Sir W. Roberts¹ shows that tea reduces the salivary digestion of starch, but that coffee and cocoa have little effect; any starch escaping salivary digestion owing to the action of the tea will be acted on by the pancreatic juice, for it has been seen in Table P that infused beverages are without effect on pancreatic digestion of the starch of bread.

Thus, people who follow the continental habit in the use of infused beverages choose the one which acts most favourably on the digestion, salivary, peptic and pancreatic of the bread, which forms the solid part of the meal; and by leaving the use of flesh meat to meals at which no infused beverage is taken, they incur no loss of nutritive material. Their after-dinner cup of coffee is less defensible: when taken as *café noir* of about 15 per cent. strength it must have a decidedly retarding action on the peptonisation of many meats, for it reduces that of even white of eggs by nearly 50 per cent. (Table I). Still the quantity taken is not large; it is often taken with a 'petit verre' of cognac, which probably stimulates the gastric secretion, and also the coffee may be useful in counteracting the effects of other beverages taken during the meal.

The third class may be considered next, out of its turn, and has as its type a lower middle-class English family consuming meat at each meal, and, at any rate in the case of the female members, drinking tea at each meal, and also in the intervals.

Breakfast and the meal called 'tea' consist of bread, accompanied at the former and usually at the latter also by meat, usually salted, or by eggs. Dinner and supper are fresh-meat meals, and it is at these that tea will most retard digestion; but this may not be entirely harmful, for this class, when fairly well-to-do, consume more meat than any other of the community; and the retarding action of the tea on digestion, by causing some of this to be excreted unabsorbed, may save them from gout and from kidney diseases, resulting from the overstrain of excreting such a great excess of nitrogenous waste.

On the other hand, among the very poor, who with difficulty obtain a single meat meal in the day, the use of tea with this meal is the cause of a serious loss, unless the meat, as is often the case, be salted (bacon or ham). Thus, if a meal be taken

¹ *Dietetics and Dyspepsia*, p. 28 et seq.

with similar proportions of meat and beverage to those used in the experiments, and if the action in the stomach be similar, some such result as the following will ensue.

Dalton¹ calculates the daily secretion of gastric juice at 3000 c.c.; if this be divided equally between three meals, it gives 1000 c.c. to each; 500 c.c. of tea, or about .88 pint, must be drunk with the meal to make the proportions similar to those of the experiments, and is not a very large amount. If the meat consumed were mutton, the tea would reduce the amount peptonised from 100 per cent., which would have been digested in the presence of the same amount of water, to 78.5 per cent.

If coffee were the beverage, the reduction would be to 70.96 per cent.; and if cocoa, to 60.0 per cent. That is to say, supposing four ounces of mutton were eaten, the tea would reduce the amount digested to very little over three ounces, the coffee to rather less than three, and the cocoa to about two and a half.

The second variety of habit above referred to is a compromise between the other two. The Anglo-Saxon race does not take kindly to a vegetable diet, and has in all ages been celebrated for its vigorous attacks on animal food. This being the case, the first meal of the day, instead of being purely vegetable, as in the first variety, has to be, like that of the richer portion of the third variety, a meat meal; but, whether by accident, or whether it points to an evolution and survival of the fittest in habit, the meats usually consumed are those which these experiments have shown to be assisted, or but slightly retarded, in their digestion by infused beverages, viz., eggs and salted meats. The afternoon tea is accompanied only by vegetable food, and the after-dinner coffee calls only for a repetition of the remarks made about it under the head of the first variety.

Having thus discussed the existing habits as to the use of infused beverages, what improvements can be suggested?

In the habits of the first and second varieties, very few: the breakfast of bread and tea or coffee is best from the point of view of its digestibility, but, if habit or the need of more nitrogenous food make meat at breakfast a necessity, little exception can be taken to the use of eggs or salt meat.

No more tea or other infused beverage should be taken until,

¹ *Human Physiology*, p. 162.

at any rate, 4 or 5 p.m., when the 'kettledrum' cup of tea and morsel of bread and butter cannot injuriously affect digestion, for the stomach will have had ample time to dispose of luncheon taken at 1.30 or 2 p.m., and the tea will, in its turn, have been absorbed or passed through the pylorus before dinner at 6.30 or 7. After this meal, it would be as well if no more infused beverage were taken, though a cup of coffee not so strong as 15 per cent. can do little harm about 9 o'clock, and may be necessary if work has to be done in the evening.

Thus far, the use of tea and coffee have been chiefly considered: with regard to that of cocoa, reasons have been given for believing that its action in the stomach is not so disadvantageous as appears from these experiments; and if this be the case, cocoa comes to resemble coffee in its action, with the added advantage that it itself contains nutritious material. It must not be overlooked that the milk and sugar taken with the other beverages convey a certain amount of nourishment: these additions have also (as shown in vol. xviii. p. 36) an action in reducing the retarding action of tea on digestion. In health, therefore, these beverages appear to be unnecessary but pleasant stimulants, in some cases having useful effects on digestion, and never necessarily harmful effects, if the time of their use and the accompanying foods be properly selected.

In illness, however, they may be decidedly harmful: in dyspepsia from atrophy or atony of the stomach, with reduction in pepsin secretion, it is increasing the work of an already overburdened organ to take tea along with almost any meat. Coffee, if otherwise suitable, may help the digestion of certain meats, but cocoa, when agreeable to the patient, is probably the best beverage of the three. In acid dyspepsia, depending on hypersecretion of gastric juice, or of hydrochloric acid, it is evident that any infused beverage will be harmful, for, as has been shown, they all retard the consumption of acid in digestion. Coffee will, again, be the least harmful. In acid dyspepsia, depending on food fermentations, any infused beverage will facilitate the fermentation if it delays the digestion of the food.

Though Sir W. Roberts appears to consider the precaution of infusing tea for two minutes only as useless, it has been shown (Table M) that this reduces the retarding effect on digestion,

and this and the removal of the tannic acid by gelatine should be borne in mind in regulating the use of tea by dyspeptic patients. Actions of these beverages on the secretion and mobility of the stomach are of necessity neglected in these experiments, but must be considered in giving advice about their use. Coffee is said by Gerard¹ to increase the secretion of gastric juice, and by Schutz² to increase the muscular movements; tea, on the other hand, is said to reduce both.³

In flatulent dyspepsia, tea is again to be avoided, for it was shown (vol. xviii. p. 34) that it caused an increased evolution of gas in the digestion of beef, but coffee was without effect.

In CONCLUSION, the deductions to be drawn from the experiments here described may be summarised as follows :—

I. Infused beverages, as a rule, retard the peptic digestion of albuminoid food stuffs,—coffee the least, and cocoa the most.

II. The meats which have been grouped together as breakfast meats and the vegetable albuminoids are the least hindered in digestion, and some are assisted.

III. The active agent in producing this retardation is chiefly the tannic acid, which acts by coagulating uncooked albuminoids, by tanning the gelatinous matter of the meat and by precipitating the syntonin and peptones as formed. There is, further, its action, chiefly in the case of tea, in retarding the conversion of syntonin into peptone. In the case of cocoa, the clogging action of the suspended solids largely contributes to the retarding action of this beverage in these experiments.

IV. All the beverages retard the consumption of acid during digestion.

V. They appear not to affect tryptic digestion of albuminoids by personally prepared pancreatic solutions.

VI. The beverages also appear to be without effect on the pancreatic digestion of starch by similar solutions.

VII. The dietetic application of these facts points to the use, in health, of vegetable food and one of the 'breakfast' meats (eggs or salted meat) at meals at which these beverages were taken.

¹ *Archive de Phys.*, 1889, No. 3.

² *Lancet*, vol. i., 1887, p. 843.

³ M'Kechnie, *Lancet*, 1895, vol. ii. p. 998.

VIII. In illness, in dyspeptic states the use of these beverages with meats, whose digestion they retard, is to be avoided, whether the dyspepsia arise from stomach atrophy, hyperacidity, or from flatulence.

In comparing this summary with that given in vol. xviii. p. 37, it is gratifying to note the general agreement between the two, showing that frequent repetitions by varied processes of the digestion experiments, and of the methods of estimating the results, lead to the same conclusions, which may therefore be taken to express well-founded facts.

TABLES.

TABLE A.—‘Factor’ Experiments with personally prepared Digestive Fluids.

| | Peptic Digestion. | Tryptic Digestion. | Dialysis. | Totals. |
|---------------|-------------------|--------------------|-----------|---------|
| | grms. | grms. | grms. | grms. |
| Water, . . . | ·0005 | ·0014 | ·0044 | ·0063 |
| Tea, . . . | ·0010 | ·0014 | ·0049 | ·0073 |
| Coffee, . . . | ·0009 | ·0017 | ·0053 | ·0079 |

TABLE B.—‘Factor’ Experiments.

| | Peptic Digestion. | Tryptic Digestion. | Dialysis. | Totals. |
|---------------|-------------------|--------------------|-----------|---------|
| | grms. | grms. | grms. | grms. |
| Water, . . . | ·0003 | ·0010 | ·0052 | ·0065 |
| Tea, . . . | ·0004 | ·0015 | ·0050 | ·0069 |
| Coffee, . . . | ·0004 | ·0015 | ·0050 | ·0069 |
| Cocoa, . . . | ·0004 | ·0008 | ·0031 | ·0043 |

TABLE C.—*Total Dialysable Nitrogen of 10 c.c. of the Undigested Beverages.*

| | |
|-------------------|----------------|
| Tea, | grms. ·0005 |
| Coffee, | ·0004 |
| Cocoa, | ·0005 |

TABLE D.—*'Factor' Experiments with the less Important Beverages.*

| Beverages. | Peptic Digestion. | Tryptic Digestion. | Dialysis. | Totals. |
|---------------------------------|-------------------|--------------------|-----------|---------|
| | grms. | grms. | grms. | grms. |
| Water, | ·0004 | ·0018 | ·0042 | ·0064 |
| Green Tea, | ·0007 | ·0030 | ·0078 | ·0115 |
| Tea with Soda, | ·0007 | ·0028 | ·0070 | ·0105 |
| Tea, Compressed, | ·0006 | ·0018 | ·0048 | ·0072 |
| Tea, Cheap Congou, | ·0007 | ·0027 | ·0063 | ·0097 |
| Coca, | ·0007 | ·0026 | ·0068 | ·0101 |
| Coffee, 15 per cent., | ·0005 | ·0011 | ·0031 | ·0047 |
| Chocolate, | ·0006 | ·0014 | ·0044 | ·0064 |
| Khola Paste, | ·0006 | ·0013 | ·0043 | ·0062 |
| Water, | ·0005 | ·0022 | ·0045 | ·0072 |
| Maté, | ·0005 | ·0022 | ·0049 | ·0076 |
| Arab Coffee, | ·0005 | ·0021 | ·0048 | ·0074 |
| Coffee with Chicory, | ·0005 | ·0018 | ·0059 | ·0082 |
| Cocoa Nibs, | ·0010 | ·0015 | ·0048 | ·0073 |
| Cocoatina, | ·0005 | ·0016 | ·0040 | ·0061 |
| Miserables, | ·0006 | ·0018 | ·0053 | ·0077 |
| Guarana, | ·0010 | ·0015 | ·0035 | ·0060 |

TABLE E.—*Results of Digestion Experiments with personally prepared Digestive Fluids.*

| | | | | ACTUAL RESULTS | | | PERCENTAGES | | |
|---------------------------|---|---|---|---------------------|----------------|--------|---------------------|----------------|-----------|
| | | | | White of Egg. | Roast Beef. | Bread. | White of Egg. | Roast Beef. | Bread. |
| <i>Peptic Digestion.</i> | | | | | | | | | |
| | | | | grms. | grms. | grms. | per cent. | per cent. | per cent. |
| Water, | . | . | . | ·0018 | ·0057 | ·0009 | 100 | 100 | 100 |
| Tea, | . | . | . | ·0017 | ·0053 | ·0006 | 94·42 | 92·98 | 66·66 |
| Coffee, | . | . | . | ·0018 | ·0062 | ·0009 | 100·00 | 108·75 | 100·00 |
| <i>Tryptic Digestion.</i> | | | | | | | | | |
| | | | | | | | | | |
| Water, | . | . | . | ·0019 | ·0029 | ·0006 | 100 | 100 | 100 |
| Tea, | . | . | . | ·0015 | ·0014 | ·0004 | 78·92 | 48·28 | 66·66 |
| Coffee, | . | . | . | ·0019 | ·0017 | ·0006 | 100·00 | 58·68 | ... |
| <i>Dialysis.</i> | | | | | | | | | |
| | | | | | | | | | |
| Water, | . | . | . | ·0091 | ·0093 | ·0002 | 100 | 100 | ... |
| Tea, | . | . | . | ·0088 | ·0220* | ·0022 | 96·72 | 263·55* | ... |
| Coffee, | . | . | . | ·0104 | ·0043 | ·0017 | 115·32 | 46·24 | ... |
| <i>Totals.</i> | | | | | | | | | |
| | | | | | | | | | |
| Water, | . | . | . | ·0128 | ·0179 | ... | 100 | 100 | ... |
| Tea, | . | . | . | ·0120 | ·0287 | ... | 93·76 | 160·33 | ... |
| Coffee, | . | . | . | ·0141 | ·0122 | ... | 110·15 | 68·16 | ... |

* Dialyser leaked.

TABLE F.—Actual Results.

| | White of Egg.* | Yolk of Egg. | Roast Beef.† | Salt Beef.† | Ham. | Mutton. | Fowl. | Fish.‡ | Bread. | Potato. |
|--------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|------------------|------------------|
| Peptic Digestion. | | | | | | | | | | |
| Water, | grms. ·00102 | grms. ·00246 | grms. ·00462 | grms. ·00368 | grms. ·00575 | grms. ·00265 | grms. ·00461 | grms. ·00229 | grms. ·00085§ | grms. ·00178* |
| Tea, | ·00099 | ·00269 | ·00303 | ·00288 | ·00763 | ·00208 | ·00386 | ·00201 | ·00093§ | ·00187* |
| Coffee, | ·00107 | ·00261 | ·00383 | ·00218 | ·00692 | ·00188 | ·00371 | ·00362 | ·00082§ | ·00213 |
| Cocoa, | ·00096 | ·00138 | ·00204 | ·00204 | ·00475 | ·00159 | ... | ·00178 | ·00095§ | ·00231‡ |
| Tryptic Digestion. | | | | | | | | | | |
| Water, | ·00114 | ·00175 | ·00174 | ·00232 | ·00476 | ·00129 | ·00237 | ·00154 | — ·00004‡ | ... |
| Tea, | ·0089 | ·00173 | ·00108 | ·00218 | ·00683 | ·00184 | ·00137 | ·00084 | — ·00013‡ | ... |
| Coffee, | ·00114 | ·00265 | ·00124 | ·00208 | ·00604 | ·00055 | ·00384 | ·00150 | — ·00011‡ | ... |
| Cocoa, | ·00058 | ·00145 | ·00090 | ·00115 | ·00140 | ·00060 | ... | ·00082 | ·00067‡ | ... |
| Dialysis. | | | | | | | | | | |
| Water, | ·00632 | ·00945 | ·00933 | ·00942 | ·01622 | ·00667 | ·01054 | ·00861 | — ·00124‡ | ... |
| Tea, | ·00496 | ·00845 | ·00572 | ·00787 | ·01706 | ·00573 | ·00573 | ·00533 | — ·00131‡ | ... |
| Coffee, | ·00646 | ·00975 | ·00757 | ·00971 | ·01953 | ·00443 | ·01275 | ·00849 | — ·00105‡ | ... |
| Cocoa, | ·00500 | ·00711 | ·00456 | ·00354 | ·00505 | ·00472 | ... | ·00280 | ·00175‡ | ... |
| Totals. | | | | | | | | | | |
| Water, | ·00848 | ·01366 | ·01569 | ·01537 | ·02673 | ·01061 | ·01752 | ·01244 | ... | ... |
| Tea, | ·00634 | ·01287 | ·00983 | ·01293 | ·03153 | ·00965 | ·01046 | ·00818 | ... | ... |
| Coffee, | ·00867 | ·01501 | ·01264 | ·01397 | ·03254 | ·00686 | ·01980 | ·01361 | ... | ... |
| Cocoa, | ·00654 | ·00994 | ·00750 | ·00673 | ·01120 | ·00697 | ... | ·00540 | ·00372 | ... |

* Average of three experiments. † Average of four experiments. ‡ Average of two experiments. § Average of five experiments.

TABLE G.—Percentage Results.

| | White of Egg.* | Yolk of Egg. | Roast Beef.† | Salt Beef.‡ | Ham. | Mutton. | Fowl. | Fish.‡ | Bread. | Potato. |
|--------------------|----------------|--------------|--------------|------------------|------------------|------------------|------------------|------------------|-------------------|-------------------|
| Peptic Digestion. | | | | | | | | | | |
| Water, | . | . | . | per cent. 100 | per cent. 100 | per cent. 100 | per cent. 100 | per cent. 100 | per cent. 100§ | per cent. 100* |
| Tea, | . | . | 65.58 | 79.33 | 132.67 | 78.50 | 72.88 | 87.78 | 109.40§ | 105.05* |
| Coffee, | . | . | 82.90 | 60.05 | 120.35 | 70.96 | 80.47 | 158.06 | 96.46§ | 119.66* |
| Cocoa, | . | . | 44.15 | 56.20 | 82.60 | 60.00 | ... | 77.73 | 111.80§ | 129.75‡ |
| Tryptic Digestion. | | | | | | | | | | |
| Water, | . | . | 100 | 100 | 100 | 100 | 100 | 100 | ... | ... |
| Tea, | . | . | 62.07 | 98.96 | 143.50 | 142.63 | 57.81 | 54.55 | ... | ... |
| Coffee, | . | . | 71.26 | 89.66 | 126.86 | 42.64 | 140.96 | 97.40 | ... | ... |
| Cocoa, | . | . | 51.72 | 49.57 | 29.41 | 46.51 | ... | 53.25 | ... | ... |
| Dialysis. | | | | | | | | | | |
| Water, | . | . | 100 | 100 | 100 | 100 | 100 | 100 | ... | ... |
| Tea, | . | . | 61.30 | 83.53 | 105.17 | 85.91 | 54.36 | 61.90 | ... | ... |
| Coffee, | . | . | 81.13 | 108.17 | 120.75 | 66.41 | 120.96 | 98.60 | ... | ... |
| Cocoa, | . | . | 48.86 | 37.58 | 31.13 | 70.76 | ... | 82.52 | ... | ... |
| Totals. | | | | | | | | | | |
| Water, | . | . | 100 | 100 | 100 | 100 | 100 | 100 | ... | ... |
| Tea, | . | . | 62.65 | 84.11 | 117.90 | 90.94 | 59.70 | 65.76 | ... | ... |
| Coffee, | . | . | 80.56 | 90.90 | 121.75 | 66.41 | 113.02 | 109.38 | ... | ... |
| Cocoa, | . | . | 47.79 | 43.78 | 41.90 | 70.76 | ... | 43.41 | ... | ... |

* Average of three experiments; † Average of four experiments. ‡ Average of two experiments. § Average of five experiments.

TABLE H.—*Actual Results with less important Beverages.*

| | Peptic Digestion. | | | Tryptic Digestion. | | | Dialysis. | | | Totals. | | |
|-----------------------------|-------------------|-------------|-----------|--------------------|-------------|-----------|---------------|-------------|-----------|---------------|-------------|-----------|
| | White of Egg. | Roast Beef. | Bread. | White of Egg. | Roast Beef. | Bread. | White of Egg. | Roast Beef. | Bread. | White of Egg. | Roast Beef. | Bread. |
| Water, . . . | grms. .0005 | grms. . . | grms. . . | grms. .0007 | grms. . . | grms. . . | grms. .0035 | grms. . . | grms. . . | grms. .0047 | grms. . . | grms. . . |
| Green Tea, . . . | .0008 | . . . | . . . | .0004 | . . . | . . . | .0041 | . . . | . . . | .0058 | . . . | . . . |
| Tea with Soda, . . . | .0006 | . . . | . . . | .0001 | . . . | . . . | .0026 | . . . | . . . | .0038 | . . . | . . . |
| Tea, Compressed, . . . | .0006 | . . . | . . . | .0004 | . . . | . . . | .0033 | . . . | . . . | .0043 | . . . | . . . |
| Tea, Cheap Congou, . . . | .0009 | . . . | . . . | .0008 | . . . | . . . | .0073 | . . . | . . . | .0090 | . . . | . . . |
| Coca, . . . | .0007 | . . . | . . . | .0006 | . . . | . . . | .0047 | . . . | . . . | .0060 | . . . | . . . |
| Chocolate, . . . | .0010 | . . . | . . . | .0009 | . . . | . . . | .0047 | . . . | . . . | .0066 | . . . | . . . |
| Khola Chocolate, . . . | .0006 | . . . | . . . | .0002 | . . . | . . . | .0029 | . . . | . . . | .0037 | . . . | . . . |
| Water, . . . | .0006 | .0050 | .0005 | .0006 | .0024 | — .0009 | .0049 | .0181 | — .0007 | .0061 | .0254 | . . . |
| Maté, . . . | .0007 | . . . | . . . | .0006 | . . . | . . . | .0045 | . . . | . . . | .0058 | . . . | . . . |
| Coffee, 15 per cent., . . . | .0008 | . . . | . . . | .0007 | . . . | . . . | .0027 | . . . | . . . | .0037 | . . . | . . . |
| Arab Coffee, . . . | .0005 | . . . | . . . | .0001 | . . . | . . . | .0047 | . . . | . . . | .0053 | . . . | . . . |
| Coffee with Chicory, . . . | .0004 | . . . | .0004 | .0003 | . . . | — .0008 | .0003 | . . . | — .0034 | .0010 | . . . | . . . |
| Cocoa Nibs, . . . | .0007 | .0024 | .00005 | .0004 | .0017 | — .0005 | .0025 | .0059 | — .0023 | .0036 | .0100 | . . . |
| Cocoatina, . . . | .0006 | .0022 | .0005 | .0005 | .0020 | — .0005 | .0032 | .0078 | — .0008 | .0043 | .0120 | . . . |
| Miserables, . . . | .0006 | . . . | . . . | .0005 | . . . | . . . | .0038 | . . . | . . . | .0049 | . . . | . . . |
| Guarana, . . . | .0008 | . . . | . . . | .0006 | . . . | . . . | .0065 | . . . | . . . | .0079 | . . . | . . . |

TABLE I.—Percentage Results of Experiments with less important Beverages.

| | Acid Digestion. | | | | Totals. | | | | | | | | |
|---------------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|-----------------------------------|---------------------------------|----------------------------|
| | Roast Beef. | | Bread. | | per cent. 100 | per cent. 100 | per cent. 100 | per cent. 100 | per cent. 100 | per cent. 100 | White of Egg. per cent. 100 | Roast Beef. per cent. 100 | Bread. per cent. 100 |
| | per cent. 100 | per cent. 100 | per cent. 100 | per cent. 100 | | | | | | | | | |
| Water, | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Green Tea, | 160.0 | 57.1 | 57.1 | 117.1 | 100 | 117.1 | 100 | 112.8 | 100 | 112.8 | 100 | 100 | 100 |
| Tea with Soda, | 120.0 | 14.2 | 14.2 | 74.2 | 100 | 74.2 | 100 | 70.2 | 100 | 70.2 | 100 | 100 | 100 |
| Tea, Compressed, | 120.0 | 57.1 | 57.1 | 94.2 | 100 | 94.2 | 100 | 91.5 | 100 | 91.5 | 100 | 100 | 100 |
| Tea, Cheap Congou, | 180.0 | 114.2 | 114.2 | 208.5 | 100 | 208.5 | 100 | 191.5 | 100 | 191.5 | 100 | 100 | 100 |
| Coca, | 140.0 | 85.7 | 85.7 | 135.7 | 100 | 135.7 | 100 | 127.7 | 100 | 127.7 | 100 | 100 | 100 |
| Maté, | 116.6 | 100.0 | 100.0 | 91.8 | 100 | 91.8 | 100 | 84.9 | 100 | 84.9 | 100 | 100 | 100 |
| Coffee, 15 per cent., | 50.0 | 116.6 | 116.6 | 55.1 | 100 | 55.1 | 100 | 60.7 | 100 | 60.7 | 100 | 100 | 100 |
| Arab Coffee, | 83.3 | 16.6 | 16.6 | 95.9 | 100 | 95.9 | 100 | 86.9 | 100 | 86.9 | 100 | 100 | 100 |
| Coffee with Chicory, | 66.6 | 50.0 | 50.0 | 6.1 | 100 | 6.1 | 100 | 16.4 | 100 | 16.4 | 100 | 100 | 100 |
| Cocoa Nibs, | 116.6 | 66.6 | 66.6 | 51.0 | 100 | 51.0 | 100 | 59.0 | 100 | 59.0 | 100 | 89.4 | 100 |
| Cocoatins, | 100.0 | 44.0 | 44.0 | 83.3 | 100 | 83.3 | 100 | 70.5 | 100 | 70.5 | 100 | 47.2 | 100 |
| Miserables, | 100.0 | 83.3 | 83.3 | 77.5 | 100 | 77.5 | 100 | 80.3 | 100 | 80.3 | 100 | 100 | 100 |
| Guarana, | 133.3 | 100.0 | 100.0 | 132.6 | 100 | 132.6 | 100 | 129.5 | 100 | 129.5 | 100 | 100 | 100 |
| Chocolate, | 200.0 | 127.1 | 127.1 | 135.7 | 100 | 135.7 | 100 | 140.4 | 100 | 140.4 | 100 | 100 | 100 |
| Khola Chocolate, | 120.0 | 28.2 | 28.2 | 82.8 | 100 | 82.8 | 100 | 78.7 | 100 | 78.7 | 100 | 100 | 100 |

TABLE J.—‘Factor’ Experiments.

| | Peptic Digestion. | Tryptic Digestion. | Dialysis. | Totals. |
|---|-------------------|--------------------|-----------|---------|
| | grms. | grms. | grms. | grms. |
| Water, | ·0004 | ·0018 | ·0042 | ·0064 |
| Tea, filtered after mixing with the Peptic Fluid, | ·0010 | ·0017 | ·0051 | ·0078 |
| Cocoa, filtered before mixing, . | ·0010 | ·0020 | ·0065 | ·0095 |

TABLE K.—Results of Digestion of White of Egg.

| | Peptic Digestion. | Tryptic Digestion. | Dialysis. | Totals. |
|---|------------------------|--------------------|-----------|-----------|
| | <i>Actual Results.</i> | | | |
| | grms. | grms. | grms. | grms. |
| Water, | ·0010 | ·0011 | ·0063 | ·0084 |
| Tea, filtered after mixing with the Peptic Fluid, | ·0011 | ·0013 | ·0054 | ·0078 |
| Cocoa, filtered before mixing, . | ·0014 | ·0006 | ·0053 | ·0073 |
| | <i>Percentages.</i> | | | |
| | per cent. | per cent. | per cent. | per cent. |
| Water, | 100 | 100 | 100 | 100 |
| Tea, filtered after mixing with the Peptic Fluid, | 104·90 | 111·40 | 86·55 | 92·09 |
| Cocoa, filtered before mixing, . | 138·23 | 54·38 | 83·38 | 86·08 |

TABLE L.—*Factors.*

| | Peptic Digestion. | Tryptic Digestion. | Dialysis. | Totals. |
|-------------------------|----------------------|-----------------------|-----------|---------|
| | grms. | grms. | grms. | grms. |
| Water, | ·0004 | ·0018 | ·0042 | ·0064 |
| Tea, two minutes, . . . | ·0008 | ·0028 | ·0044 | ·0080 |
| Tea, tannin free, . . . | ·0007 | ·0028 | ·0048 | ·0083 |
| Tea, boiled, | ·0012 | ·0028 | ·0048 | ·0088 |

TABLE M.—*Results of Digestion of Roast Beef.*

| | Peptic Digestion. | Tryptic Digestion. | Dialysis. | Totals. |
|-------------------------|----------------------|-----------------------|------------------|------------------|
| <i>Actual Results.</i> | | | | |
| | grms. | grms. | grms. | grms. |
| Water, | ·0024 | ·0014 | ·0098 | ·0136 |
| Tea, two minutes, . . . | ·0033 | ·0009 | ·0122 | ·0164 |
| Tea, tannin free, . . . | ·0042 | ·0035 | ·0139 | ·0216 |
| Tea, boiled, | ·0026 | ·0005 | ·0069 | ·0100 |
| <i>Percentages.</i> | | | | |
| | per cent. 100 | per cent. 100 | per cent. 100 | per cent. 100 |
| Water, | 136·47 | 63·12 | 124·81 | 120·49 |
| Tea, two minutes, . . . | 170·90 | 252·49 | 142·41 | 159·00 |
| Tea, tannin free, . . . | 107·34 | 32·62 | 71·00 | 73·61 |
| Tea, boiled, | | | | |

TABLE N.—*Action of Beverages, &c. on Dialysis.*

| | Water. | Tea. | Coffee. | Cocoa. | Syrup. |
|------------------------|------------------|--------------------|--------------------|--------------------|-------------------|
| <i>Actual Results.</i> | | | | | |
| 6 hours, | grms. ·0014 | grms. ·0019 | grms. ·0022 | grms. ·0014 | grms. ·0005 |
| 24 hours, | ·0019 | ·0031 | ·0028 | ·0018 | ·0029 |
| <i>Percentages.</i> | | | | | |
| 6 hours, | per cent. 100 | per cent. 135·7 | per cent. 157·1 | per cent. 100·0 | per cent. 35·7 |
| 24 hours, | 100 | 163·1 | 147·3 | 94·7 | 152·6 |

TABLE O.—*Factors.*

| | |
|------------------------|---------------|
| Cocoa, | grms. ·047 |
| Chocolate, | ·050 |
| Khola Paste, | ·011 |

TABLE P.—*Results of Pancreatinic Digestion of Bread with personally prepared Digestive Fluids.*

| | Actual Results. | Percentages. |
|-------------------|-----------------|------------------|
| | Bread. | Bread. |
| Water, | grms. ·038 | per cent. 100 |
| Tea, | ·038 | 100·0 |
| Coffee, | ·037 | 97·3 |

TABLE Q.—*Results of Pancreatinic Digestion of Bread and Potato.*

| | Actual Results. | | Percentages. | |
|-------------------|-----------------|---------|--------------|-----------|
| | Bread. | Potato. | Bread. | Potato. |
| | grms. | grms. | per cent. | per cent. |
| Water, | ·044 | ·067 | 100 | 100 |
| Tea, | ·034 | ·114 | 77·13 | 169·60 |
| Coffee, | ·041 | ·085 | 93·12 | 126·70 |
| Cocoa, | ·039 | — ·004 | 88·11 | ... |

TABLE R.—*Results of Digestion of Bread.*

| | Actual Results. | Percentages. |
|-----------------------------|-----------------|--------------|
| | grms. | per cent. |
| Water, | ·075 | 100 |
| Tea, two minutes, | ·042 | 55·8 |
| Tea, tannin free, | ·037 | 50·0 |
| Tea, boiled, | ·056 | 75·0 |

ON THE EXISTENCE OF A STERNO - CORACOIDAL
ARTICULATION IN A FŒTAL MARSUPIAL By
R. BROOM, M.D., B.Sc.

AMONG the characteristics of the Monotremes, which point to their Reptilian affinity, none is more marked than the structure of the shoulder-girdle. While in the Eutheria and in Marsupials we have the scapula either loosely connected with the sternum by means of the clavicle, or more rarely supported here by muscles and ligaments, in the Monotremes the condition agrees very closely with that found in lizards and other reptiles. The scapula, instead of being freely movable as in Marsupials, is united to a well-developed coracoid, which articulates with the sternum just in front of the first costal cartilage. In front of the coracoid there is an additional paired element, usually referred to as the epicoracoid, but concerning the homology of which there is still some doubt. Another reptilian feature is found in the presence of a large median inter-clavicle. With this remarkable development of the pectoral arch the Monotremes seemed very distinctly separated from the higher mammals.

On looking over a series of sections of a very early mammary foetal Phalanger (probably just born, and measuring 14 mm.), I recently discovered that not only is there a well-developed coracoid, but that the coracoid articulates with the sternum almost exactly as in the Monotremes. The figure on the next page represents the shoulder-girdle and sternum as seen from the outer and under side, reconstructed from a series of sections.

The scapula bears considerable resemblance to that of the adult, the chief difference being that the spine is only rudimentary at its upper part. The acromion process, which is well developed, arises practically from the anterior concave border of the scapula, a little above the glenoid cavity, by a somewhat slender process, which passes outwards and slightly downwards, then suddenly turning downwards and slightly inwards, broadens out into a moderately thick plate, which at its lower and anterior edge gives attachment to the outer end of the clavicle. The neck of the scapula is distinctly marked.

Below the neck is situated the glenoid cavity, which is very much larger proportionally than in the adult, and can be divided into two parts. The upper part looks almost directly downwards, and practically corresponds to the adult glenoid cavity, and even in the early foetus it is only this upper portion which has an articular surface for the head of the humerus. The lower part looks practically outwards; and though presenting a concavity continuous with the upper part, or glenoid cavity proper, has not such a regular, smooth surface. While the upper part of the large concavity unquestionably belongs to the scapula, it

is probable that the whole of the lower part belongs to the coracoid element.

In front of the supposed coracoidal portion of the glenoid cavity is a small cartilaginous knob, which represents the portion of the coracoid usually remaining in the adult as the 'coracoid process.' Posteriorly, the coracoid cartilage is continued by a rather narrow neck into a somewhat large, thick, pear-shaped portion, which articulates at its lower end with the sternum and with the 1st rib. For the most part it is situated a little in front of the plane of the 1st rib, so that the rib almost appears to curve behind the posterior part. At the posterior and inner

corner of the club-shaped portion of the coracoid, where it articulates with the outer part of the presternum, the cartilages of the two elements become completely blended; and about almost the same place the 1st rib ends, thus articulated with both the coracoid and the sternum.

The clavicle, which even in an intra-uterine foetus of 11 mm. is already ossified, is here well developed. The inner half is considerably stouter than the outer. At its inner end it is pointed, and passes backwards into the narrow space between the coracoid and the sternum. On the inner and anterior side of the clavicle, and between it and the front part of the presternum, is a moderate-sized cartilaginous element, which in later development becomes the inter-articular cartilage. At this stage, however, it might almost be looked upon as a cartilaginous part of the clavicle, being clasped on its posterior and inferior sides by the ossifying bone; but though thus intimately related to the clavicle, it is distinct from that bone, which has apparently no cartilaginous basis.

In a mammary foetus of *Trichosurus*, 37 mm. in length, I find the condition essentially similar to that of the adult, the coracoid being represented only by the coracoid process, and widely removed from the sternum. I have not as yet had an opportunity of completely tracing the changes brought about in the course of development, but in a mammary foetus 23 mm. in length, which I have examined, an intermediate condition is found. The coracoid process is similar to that in the larger foetus, but from it there is produced backwards and inwards a small cartilaginous process, which nearly meets the outer process of the presternum.

It may thus be concluded that during the later intra-uterine development of *Trichosurus*, and probably of other Marsupials, and for a short time after birth, there is a well developed coracoid, which, as in the Monotremes, most Reptiles, Birds and Amphibians, articulates with the sternum; and that, shortly after birth, the coracoid loses its attachment with the sternum, and becomes rapidly absorbed, only the anterior part remaining as the coracoid process.

I must express my indebtedness to Dr J. Beard for his kindness in sectioning the foetus for me.

NOTES ON THE DUODENUM AND THE PYLORUS. By
THOMAS DWIGHT, M.D., LL.D., *Parkman Professor of
Anatomy at Harvard University.*

SEVERAL years ago I made a considerable series of plastic casts of the duodenum, among which I found specimens of the principal shapes and of some very peculiar forms. Since then, in taking notes, I have given rather special attention to this. As a result of this, I came to suspect that the general accounts were in some points incorrect. During the past winter I made a more systematic study of the points at issue on a number of bodies, and have tabulated the results of observations on 54 adults. Of these, 38 were male and 16 female. Of them were 6 negroes or mulattoes and 2 Indians, whom I do not seem necessary to exclude, though they showed several peculiar forms. The method was to inflate the duodenum after the intestines had been disturbed, to take notes of its shape and position, then to take a cast in mineral wax and to repeat the notes. Unfortunately, the need of a double set of notes was not recognised till nearly twenty observations had been made, and subsequently determined the position from the observations preceding injection, and the shape from those after it.

The correct conception of the shape of the duodenum is given by Braune, as a ring not quite complete. This is the primitive form from which all others arise. When the intestine is flaccid it is maintained in a large proportion of adult duodenums, which when distended present two or three sharp angles. The difficulty of determining accurately the shape of an uninjected duodenum is very great; in many injected ones I have been in doubt whether it was more like a bad U or a bad V. Casts vary greatly in size: one is inclined to consider very large ones over-distended, but this was not the case with some of the largest, and several of the casts are strikingly small. As the pylorus and the first part of the duodenum are movable, the direction of the first part, as shown by the casts, is of little value. The

remainder is so fixed that a cast shows its shape on the whole truly. The question of the displacement of the duodenum 'en masse' by the cast is a more serious one. Sometimes, undoubtedly, the whole organ descends the whole height of a vertebral body, more often half the distance, and sometimes not at all. Usually the descent varies from 1 to 3 cm. The effect of distention by wax on the relations of the fourth part is dis-

account of the direction and relations of the duodenum and the aorta is about as follows:—The first part, forward, backward, and to the right, to the side of the vertebra. It then turns sharply, and descends to the second part. It then again bends sharply, forming the third part, properly called præ-aortic, which, usually rising behind the aorta, is said to cross the aorta, and, bending once more, forms the fourth, which is said to ascend on the left of the aorta, in front of it and the left kidney, more or less overlapping the aorta.

In the V-shape, it crosses the aorta obliquely, behind the aorta, the author who makes it descend lowest. He says it is a variable one, and names the fourth lumbar for the U-shape, and the fifth for the V-shape.

These shapes were especially considered in this investigation: the U-shape, the V-shape, and the C-shape, and the relation to which the duodenum descends, and the relation of the ascending portion, the fourth (or in the V-shape the fifth) part, to the aorta. Incidentally, several others presented themselves. We shall consider the shape, the largest part, the lowest part, the relation to the terminal part to the aorta and to the

1.—This is determined from 70 observations of the shape of the duodenum by means of casts. One was of only 14 years. 8 were male, 17 female, and 15 were old casts, of which 8 had not been noted.

As to the classification of shapes: the U- and the V-shapes are clear; the C-shape is used in Braune's sense, implying that it is imperfect; those called 'indeterminate' are mixtures of U, C, and ring, that could be put with either of the three, according to the taste of the classifier. Those not to be classified are absolutely irregular. By 'C-shape' is meant a rather rare form,

¹ *Progrès médical*, 1889.

in which the first and third parts are very long, the second short, and the fourth wanting or rudimentary. The first and third parts may be almost in contact. The striking feature of the table are the relative frequency of the V-shape in women and the preponderance of the irregular forms in men. All the C-shaped specimens were from men.

| | Male. | Female. | Sex unknown. |
|---------------------------|-------|---------|--------------|
| U-shaped, | 10 | 3 | 9 |
| V-shaped, | 9 | 9 | 3 |
| Ring-shaped, | 2 | 2 | ... |
| Indeterminate, | 7 | 3 | 1 |
| C-shaped, | 5 | ... | ... |
| Not to be classified, . . | 5 | ... | 2 |
| | 38 | 17 | 15 |

A peculiar variation of the V was seen once or twice. Usually the second part descends vertically, but in these cases it runs forward so as to make the V more symmetrical. Another peculiar shape is triangular, in which the first part runs considerably upwards, and the second part is rather long, with about equal angles between it and the first and third parts, which almost meet. As the direction of the first part is largely accidental in a cast, this form has a doubtful claim to recognition. The first flexure is, however, often sharp and dependent on the adherence of the walls of the first and second parts. The same may be said in many cases of the bend below the latter. The length of the various sides varies so much that it is not worth while to give average dimensions. The converse of the C-shape described above is found with a very long second part. I have seen no such extraordinary coils as in the case described by Schieferdecker,¹ but several very curious ones. Some of them might be compared to an S placed on its side, with an additional coil at its termination over the left kidney, from which it returns,

¹ *Arch. für Anat. und Entwickl.*, 1887.

behind the peritoneum, to near the proper place for the duodeno-jejunal flexure.

Size.—This varies much. In all casts the first part is strikingly different from the others, being rather egg-shaped and smooth, presenting neither the valves which appear in the second, nor the numerous small irregular folds which are often seen, particularly on the posterior aspect of a good cast, in the second and third parts. The largest circumference is usually at the second or third part. The two largest, 18 and 19 cm., are at the second. In at least one case of an immense second part, it was evident from the condition before the injection that the size in no way depended on over-distention.

The lowest point is decidedly lower than is usually stated in English works. Jonnesco's statement is the most correct, though I differ from him with regard to the V-shaped, which he says descends to the fifth lumbar. My statistics are based on 54 adult duodena, of which 38 were male and 16 female. I do not give accurate statistics, because I distrust the method used in some of the observations, but I know that my results justify fully the rather general conclusions that follow. The great majority of duodena in both sexes have the lowest point opposite the fourth lumbar, or the discs above and below it; about one-quarter opposite the third; and only some half-dozen of the 54 opposite the fifth. One of the latter that descended too near the promontory had a great scrotal hernia, and was therefore pathological. The mean female duodena, in which the V-shape preponderates, is rather lower than in the male, but not strikingly.

The Relation of the Terminal Part to the Aorta and Peritoneum.

The usual statement that the third part crosses the aorta, presumably with no peritoneum intervening, and that the fourth ascends on its left, is incorrect. Jonnesco admits that this last part is much less firmly attached than the second and third, so that it slides easily. He states that when the fourth part ascends vertically it lies on the lower third or quarter of the left kidney, and that in the V-shape only a little touches the kidney. He says that the second part is præ-renal, and the fourth also; but if the expression may be excused, it is less præ-renal. In

point of fact, it is only exceptionally that the fourth part is prærenal at all. In the 54 cases already mentioned, the duodenum was on the right of the aorta till just before the terminal flexure 26 times. It was wholly on the right 6 times. The fourth part lay in front of the aorta 11 times, and the third part actually crossed the aorta 11 times. In many of the cases in which the gut lay on the front of the aorta as it ascended, or just before the final flexure, and in some of those in which the third part crossed the aorta, a fold of peritoneum lay between the two. It is impossible to give definite statistics on this point, for the attachment of the peritoneum is so lax that it is very easily displaced. I have on several occasions seen a duodenum empty, or moderately inflated, lying on the right of the aorta, and partly overlapping it, with a fold of peritoneum between, which was completely displaced to the left when the gut was strongly distended. In other words, the left fold of the mesentery seemed to arise from the right of the aorta in the normal condition, but to be pushed to the left of it with distention of the duodenum.

In the infant, the attachment is so lax that it is very hard to determine whether it is really on the left, the front, or the right. I incline to the opinion that it is along the right of the aorta, and have in several adults found what seemed to be a persistence of that condition. In cases of V-shaped duodena, it is not uncommon to find the last part ascending along the right side of the right iliac and then of the aorta, with only the very end in front of the latter, and a fold of peritoneum between. Let such a gut be distended, and the peritoneal fold is, as a rule, forced out of the furrow between it and the aorta, but not always. Sometimes, indeed, in spite of any amount of distention, the peritoneum always passes in front of the aorta to the right. Hartmann¹ has the most correct idea of the fourth portion, but apparently does not sufficiently recognise the frequency of what he considers an occasional arrangement. "La situation de cette 4me. portion n'est pas absolument fixe; ordinairement prevertebrale, elle se termine à gauche de la colonne lombaire; nous l'avons vue entierement à droite de la ligne médiane, remontant obliquement en haut et à gauche, atteignant au niveau

¹ *Bull. Soc. Anat.*, Paris, 1889.

de sa terminaison, le partie antero-laterale droite de l'aort abdominale." The third part cannot be called præ-aortic.

THE PYLORUS.

Though it is understood that the opening may be oval, it is generally described as circular. It is only on hardened specimens or casts that this can be determined. The following table of 30 observations on casts shows that it is practically always oval. I have not been able to ascertain that the long axis of the oval has any definite direction. If the method of casts is liable to any error in recording the size, it is evidently on the side of excess. These measurements in millimetres show a considerable range of variation. The average size, omitting fractions, is 14×11 mm.

Diameters of the Pylorus.

| | |
|----------------|----------------|
| 7×4 | 15×10 |
| 8×8 | 15×11 |
| 9×8 | 15×12 |
| 10×7 | 15×12 |
| 10×8 | 15×13 |
| 10×10 | 15×14 |
| 11×8 | 16×12 |
| 11×9 | 16×13 |
| 12×7 | 16×14 |
| 12×10 | 16×15 |
| 12×11 | 17×15 |
| 13×10 | 18×15 |
| 13×10 | 18×17 |
| 13×11 | 20×16 |
| 14×9 | 20×18 |

ON SOME POINTS IN COMPARATIVE MYOLOGICAL
NOMENCLATURE. By BERTRAM C. A. WINDLE, D.Sc.,
M.D., M.A., *Professor of Anatomy in Mason College, Bir-
mingham*, and F. G. PARSONS, F.R.C.S., F.L.S., F.Z.S.,
Lecturer on Comparative Anatomy at St Thomas's Hospital.

THE unsatisfactory condition of comparative myological nomenclature can scarcely have failed to attract the attention of any person working at that branch of science; indeed, the efforts of Humphry, Gadow, Hoffmann, Fürbringer, Strauss-Durckheim, and others to introduce a more accurate series of names show the necessity which exists, and, it may be added, demonstrate the difficulties which attend the realisation of such a project. Founded, as it is, upon the nomenclature of human anatomy, that of comparative myology is full of terms either wholly or largely inapplicable to the lower mammals—terms which relate to the position of a muscle in its relation to the erect posture of man, to its peculiar attachments in him, to its shape or to its action.

And with regard to the extra muscles, if one may so call them, which exist widely amongst the lower mammals, but not at all or only rarely in man, these possess a wealth of synonyms which often renders the task of ascertaining precisely what muscle a writer is dealing with one of no small difficulty. The rock upon which most schemes of nomenclature have foundered has been a too slavish adherence to a single system. Thus have been evolved terms such as *M. epicondylo-fibulo-tibio-digitalis profundus*, for which existence is far from being sufficiently protracted. In dealing with this subject, it must be remembered that, as in most cases where vested interests are at stake, success is only possible as the result of a compromise. There are some terms which are so consecrated by usage as to offer an all too stubborn resistance to the efforts whether of individuals or of committees.

In offering the few suggestions which this paper contains, we allude almost exclusively to those muscles whose nomenclature

seems to us most urgently in need of either revision or decision ; that is to say, either of a complete alteration of name, or of a selection of one from amongst the numerous titles with which successive godfathers have endowed some unoffending muscle. We have not attempted to proceed upon any rigid system, our main desires having been to avoid the use of terms depending upon posture, using instead those which bear relation to the axis of the body, and, where possible, to employ names which indicate the position and connections of the muscle, as suggested by Gadow. With these few remarks as preface, we proceed to the consideration of the muscles *seriatim*.

Rectus capitis anticus ma. et mi. (*Longus capitis* and *Rectus capitis anticus* of the German Committee). Here the word *ventralis* should be substituted for *anticus* in either case.

Rectus capitis posticus ma. et mi. It is not possible to use an exactly parallel nomenclature for these muscles, since the former is so very frequently bilaminar. This being the case, we suggest the use of the terms *Rectus capitis dorsalis superficialis, medius et profundus*, the first two constituting the major of human anatomy, if indeed this is the correct morphology, and the last the minor.

Obliquus capitis superior et inferior would be much better described as *obliquus capitis* and *obliquus colli*.

Digastric: this muscle is so frequently destitute of a central tendon that the name derived from its appearance in the human subject is clearly a misnomer when used universally. This muscle has also been called *Biventer*, *M. occipitalis mandibulæ inferioris*, *M. mandibulæ* (Krause), *Depressor maxillæ inferioris* (Bronn). We think that a name differing but slightly from the last named, viz., *Depressor mandibulæ*, describes this muscle most simply and correctly.

Sterno-hyoid: this muscle, which has also been called *sterno-glossus* and *sterno-maxillaris*, is not always correctly described when called by the name which it bears in human anatomy, since it is attached to the lower jaw in *Bathyergus*, to the median raphé of the mylo-hyoid in *Myopotamus* and *Hydromys*, and is a sterno-mandibular muscle in *Myrmecophaga*, *Choloepus*, and other edentates. This is, however, one of the instances in which we do not think that any change is advisable. Perfection is not to be looked for in all cases, and it is distinctly inadvisable to make

any alteration unless it promises a very substantial improvement in accuracy upon that which has been consecrated by years of employment.

Scaleni: the names of these muscles certainly require revision. The muscle known in human anatomy as *anticus*,—that is to say, that portion of the mass which lies in a ventral position to the subclavian artery and the brachial plexus,—is practically non-existent amongst, for example, the Carnivora, where the whole scalene mass lies dorsal to the artery and plexus. We prefer to call that portion of the mass which lies ventral to the above-named structures, when it exists, *scalenus ventralis*. The remaining parts, which are dorsal to the artery and nerves, we describe as *longus* and *brevis*, as we believe that those terms convey a more accurate impression of the real relations of the different factors.

Trapezius: it is perhaps over-bold to suggest any alteration in the name of this muscle. It has been called *triangularis scapulae*, and by Strauss-Durckheim *Cucullaris*. He subdivides it into *clavo-*, *acromio-*, and *spino-cucullaris*, and this terminology we ourselves agree with, merely suggesting the substitution of *dorso-cucullaris* for the last of the three terms.

Cephalo-humeral: this term has been applied to a composite muscle met with in the non-clavicate or parvi-clavicate mammals, which is made up of the clavo-cucullaris, the clavicular part of the deltoid and the cleido-mastoid. We prefer the term which has just been used to that of *levator humeri*, which has also been applied to this combination of muscles.

Levator claviculae (Wood): this muscle is even more richly endowed with names than a royal prince, as it has been called *cleido-omo-transversaire* (Testut), *Levator scapulae major, ant.* (Douglas and Burmeister), *Omo-trachelian* and *Acromio-trachelian* (Cuvier and Meckel), *Clavo-trachelian* (Church and Duvernoy), *Basio-humeralis* (Krause), *Kopf-arm-muskel* (Peyer), *Transverso-scapulaire* (Strauss-Durckheim), *Omo-atlanticus* (Haughton), *Cervico-humeral* (Humphry), *Omo-cervical* (Bischoff), *Cleido-atlanticus* and *Cleido-epistrophicus* (Gruber), *Atlanto-acromial* (Coues), *Levator scapulae* (Sidebotham), *Trachelo-clavicularis* (Naumann), *Omo-cleido-transversarius* (Bronn). We prefer ourselves the term *omo-trachelian* as indicating with the greatest accuracy the attach-

ments of the muscle, since its origin may be from almost any of the cervical transverse processes, or even from the basi-occipital, while its insertion is generally into the acromion process, but in some cases, *e.g.*, primates, when it is present, cheiroptera, etc., into the outer third of the clavicle.

Rhomboidei: the names of these muscles clearly require revision, and we prefer to call the more cephalic portion, which may or may not reach the occiput, *rhomboides capitis et colli*, and the more caudal part, *rhomboides thoracis*. To these two parts we would add a third, by the name of *rhomboides profundus*. We apply this name to a muscle which has also been called *Trachelo-scapular* and *Levator scapulæ minor*; it is a highly characteristic muscle amongst the mustelidæ, and passes from the transverse process of the atlas to the root of the scapular spine. We regard it as a displaced fragment of the rhomboid mass, and hence suggest the above-mentioned name.

Serratus posticus: we prefer to call this muscle *serratus dorsalis*; and when it consists of two parts, to name them *thoracis* and *lumbalis* respectively.

Levator anguli scapulæ: this muscle draws forward the scapula in most animals, and a name is distinctly required for it which, whilst non-committal as regards its action, will indicate its very common fusion with serratus magnus. Perhaps the term *serratus colli* might be applied to it, when it would be possible to speak of the above-mentioned condition as one in which serratus magnus and serratus colli form a continuous sheet.

Sterno-scapularis, also called *pectoralis longus* by Bendz. We prefer the former term, with its subdivisions of *sterno-clavicularis* or *subclavius* and *claviculo-scapularis*.

Rectus abdominis: a better name for a muscle which often extends as far forwards as the first rib would be *rectus ventralis*.

Pectorales: we hesitate to attempt to name this most complicated group of muscles. One of us has indeed attempted to do so, and has used the terms superficial and deep manubrials, gladiolar, costal, abdomino-humeral, and pectoralis quartus for the different factors of the mass. The *abdomino-pectoral* has also been called *costo-humeral* (Huxley), *Brachio-abdominal* (Zenker), *Portion ventrale* (Cuvier and Laurillard), and *Pectoralis quartus* (Macalister). We prefer the term *abdomino-pectoral*. The deep

manubrial part is also known as *pectoralis minimus*, and this perhaps is as good a name for it as any other.

Biceps cubiti: this is a misleading term, as the muscle so often possesses only one head. It has been called *flexor antibrachii* by Bronn, but we prefer the name of *flexor longus cubiti*, and would apply that of *flexor brevis cubiti* to the *brachialis anticus*, and muscle which has also been called *Brachiaeus* (Macalister), and *Brachialis internus* (Bronn and the German Committee).

Coraco-brachialis: the terminology suggested by Wood of *brevis*, *medius*, and *longus* is well understood, and sufficiently describes the different factors of this muscle. We think that the term *rotator humeri* sometimes applied to the first-named part of this muscle should be discarded.

Triceps: this is a misleading term, since the muscle often has four or even more heads, and that of *extensor cubiti* would seem to be more suitable.

Latissimo-olecranalis: a muscle with many synonyms, since it has been called *Dorsi-epitrochlearis* (Wood, Duvernoy, Mivart and Murie), *Accessoire du grand doreal* (Broca), *Quatrième extenseur de l'avant-bras* (Cuvier and Laurillard), *Chef posterior du triceps* (Milne-Edwards), *Omo-anconeus* (Devis), *Latissimo-condyloideus* (Bischoff), *Extensor cubiti* (Naumann), *Anconeus gracilis* (Bendz), *Anconeus quintus* (Gruber), and *Dorso-antibrachialis* (Westling). For this well-known slip, which comes almost invariably from the tendon of the latissimus dorsi, though it may originate from the teres major, we prefer the term of *Latissimo-olecranalis*. We believe that it belongs to the extensor cubiti or triceps, and that its proper insertion is with that muscle into the olecranon, though it may fail to reach that bone, and end on the extensor in the arm.

Epitrochleo-anconeus (Gruber): this very definite little muscle has been called also *Anconeus parvus* (Rupp), *A. minimus* (Burmeister), *A. internus* (Cuvier and Humphry), *A. sextus* (Galton), and *Epitrochleo-cubitalis* (Testut). We prefer the name *epitrochleo-olecranalis*.

Glutei: five of these muscles have to be taken into account; and, in spite of the ridicule thrown upon that name by Gadow, we do not think that it is likely to be discarded. The names, however, applied to the three parts in human anatomy are

inapplicable in comparative, and the terms *ecto-*, *meso-*, and *ento-glutei* should be substituted. For *gluteus quartus* (Haughton), also called *scansorius*, and *epiméral* (Strauss-Durckheim), we prefer the name of *gluteus ventralis*, which expresses its relations to the remaining portions of the mass. The last and least common segment, *gluteus quintus* of Macalister, has been also spoken of as *gluteus quartus* by Watson and Young, according to whom it was first described by Douglas as *M. parvus in articulatione femoris situs*. As this muscle, which arises from the iliac portion of the acetabulum, over the reflected tendon of the rectus when that is present, is much the deepest factor, we propose for it the name of *gluteus profundus*.

Agitator caudæ; also called by Strauss-Durckheim, *parameral*. We prefer the name *caudo-femoralis*. It is true that this term has been applied to the pyriformis by Gadow; but as writers on mammalian myology have not accepted such alteration, which for our part we consider to be unnecessary, we think this objection may be waived.

Gracilis: also called *adductor latus anticruris* (Bendz). The term used in human anatomy is highly inapplicable in many cases in comparative myology. We should suggest naming this muscle *adductor cruris*; and when, as is not infrequently the case, it is double, the two portions can be distinguished as *anticus* and *posticus*.

Adductors: we are doubtful whether in by far the greater number of mammals it is possible in any accurate manner to homologate the factor of the adductor mass with those of human anatomy: often only two layers can be made out; and, as we shall point out, a portion of what is adductor magnus in man is often detached from that muscle in other mammals. It is better, therefore, to use non-committal names, and Macalister has used those of *primus*, *secundus*, and *tertius*, numbering the muscles from behind forwards. For our own part, we dislike the numerical method of naming muscles, since, as in this case, there is no reason why the numbering should not go the other way; and since the terms *dorsalis* and *ventralis* are inadmissible, owing to the rotation of the limb, we should suggest that where there are three of these muscles they should be called *anticus*, *medius*, and *posticus*, the middle name being omitted in the bilaminar condi-

tion. The suffixes in question do not here suffer from the same disability as in other parts of the body.

Ischio-supracondyloideus: we suggest this name for that portion of the human adductor magnus which is attached to the condyle of the femur. We have no doubt that this is a part of the semi-membranosus with which it is fused in some animals, whilst in others it is a completely distinct muscle. By giving it a distinctive name it will be easy to describe its exact relations to the above-mentioned muscles, without the necessity of employing a periphrase.

Quadriceps femoris (of the German Committee): we prefer to call this *Quadriceps extensor cruris*, and to speak of its separate parts as *superficialis* (*rectus femoris*), *profundus* (*crureus*), *lateralis* (*vastus externus*; *v. lateralis* of the German Committee), and *mesialis* (*vastus internus*). Perhaps the name of *tensor capsulae* might be applied to the *subcrureus*.

Sartorius: this muscle would be better named, we think, *ilio-tibialis*, as its present appellation is ridiculous in comparative anatomy.

Biceps femoris: this muscle has frequently only one head; and when it does justify its name, the two heads are not those of human anatomy. We think, therefore, that it would be better to call it *flexor cruris lateralis*. Gadow has applied a somewhat similar term, *flexor tibialis externus*, to the semi-membranosus, the semi-tendinosus being the fellow internus. Whilst agreeing that the terms of human anatomy are unsatisfactory, we are doubtful as to the policy of changing them; but if change is to be made, perhaps Gadow's terms are as satisfactory as can be devised.

Bicipiti accessorius: we think that the term *tenuissimus*, which has also been applied to this muscle, is a better name, as it at least describes its invariable character.

Flexor longus digitorum and *fl. longus hallucis*: Dobson's alternative names of *flexor tibialis* and *fl. fibularis*, which so much more accurately express the nature of these muscles in comparative myology, have already been so widely accepted as to require no more than mention.

By way of summary, we add a list of present and suggested names.

Present.

R. Cap. anticus ma. et mi.
 „ „ posticus major.
 „ „ „ minor.
 Obliquus capitis superior.
 „ „ „
 Digastric.
 Scalenus anticus.
 Scaleni medius et posticus.
 Trapezius.
 Levator humeri.
 „ claviculæ.
 Rhomboidei.
 Levator scapulæ minor.
 Serratus posticus.
 Levator anguli scapulæ.
 Rectus abdominis.
 Pectoralis quartus.
 Biceps cubiti.
 Brachialis anticus.
 Triceps.
 Dorsi-epitrochlearis.
 Epitrochleo-anconeus.
 Gluteus maximus.
 „ medius.
 „ minimus.
 „ quartus.
 „ quintus.
 Agitator caudæ.
 Gracilis.
 Adductores.
 Quadriceps femoris.
 Rectus femoris.
 Crureus.
 Vastus externus.
 „ internus.
 Subcrureus.
 Sartorius.
 Biceps femoris.
 Bicipiti accessorius.

Suggested.

R. cap. ventralis ma. et mi.
 „ „ dorsalis superficialis et
 medius.
 „ „ „ profundus.
 Obliquus capitis.
 „ colli.
 Depressor mandibulæ.
 Scalenus ventralis.
 Scaleni longus et brevis.
 Clavo-, Acromio-, et Dorso-cucul-
 lares.
 Cephalo-humeral.
 Omo-trachelian.
 Rh. capitis et colli.
 „ thoracis.
 „ profundus.
 S. dorsalis, thoracis et lumbalis.
 „ colli.
 R. ventralis.
 Abdomino-humeralis.
 Flexor longus cubiti.
 „ brevis „
 Extensor cubiti.
 Latissimo-olecranalis.
 Epitrochleo-olecranalis.
 Ecto-gluteus.
 Meso „
 Ento „
 Gl. ventralis.
 „ profundus.
 Caudo-femoralis.
 Adductor cruris.
 „ anticus, medius et posticus.
 Quadriceps extensor cruris.
 Superficialis.
 Profundus.
 Lateralis.
 Mesialis.
 Tensor capsulæ.
 Ilio-tibialis.
 Flexor cruris lateralis.
 Tenuissimus.

**A CASE OF AN ADDITIONAL PRESACRAL
VERTEBRA. By R. J. GLADSTONE.**

THE specimen, the spinal column of an adult male European, has the following vertebral formula :—

7 Cervical
13 Bearing ribs.
5 Of the lumbar type.
5 Sacral.
4 Coccygeal.

—
34

The 11th and 12th ribs, with the vertebræ which correspond to them, apparently accord with the normal 11th and 12th costo-vertebral segments of the thoracic region ; and the 13th ribs, which are carried by the 20th vertebra to two lumbar ribs which have been developed in connection with the first lumbar vertebra.

The cartilages of the 11th rib are $\frac{3}{4}$ inch long, and in the recent state floated free in the abdominal wall. The ribs themselves are 8 inches in length. They articulate with the sides of the body and pedicles of the 11th dorsal vertebra, but not with its transverse processes. The upper part of the rib-head articulates to a slight extent with the lower border of the 10th dorsal vertebra, and there is an interarticular ligament on each side. The 11th ribs thus correspond with the normal type in so far as they are 'floating ribs,' and in the absence of a tuberosity for articulation with the transverse process of the vertebra. They differ in articulating with the side of the vertebra next above, as well as with the 11th, and in possessing an interarticular ligament.

The 12th ribs, also free, are, including their cartilages, $6\frac{1}{2}$ inches long. They articulate by their heads with the pedicles of the 12th D.V. They have a slight angle, no tuberosity. They do not articulate with the 11th D.V., but on the right side there is an interarticular ligament, connecting the rib-head with the intervertebral disc.

The 13th rib of the right side, measuring to the tip of the

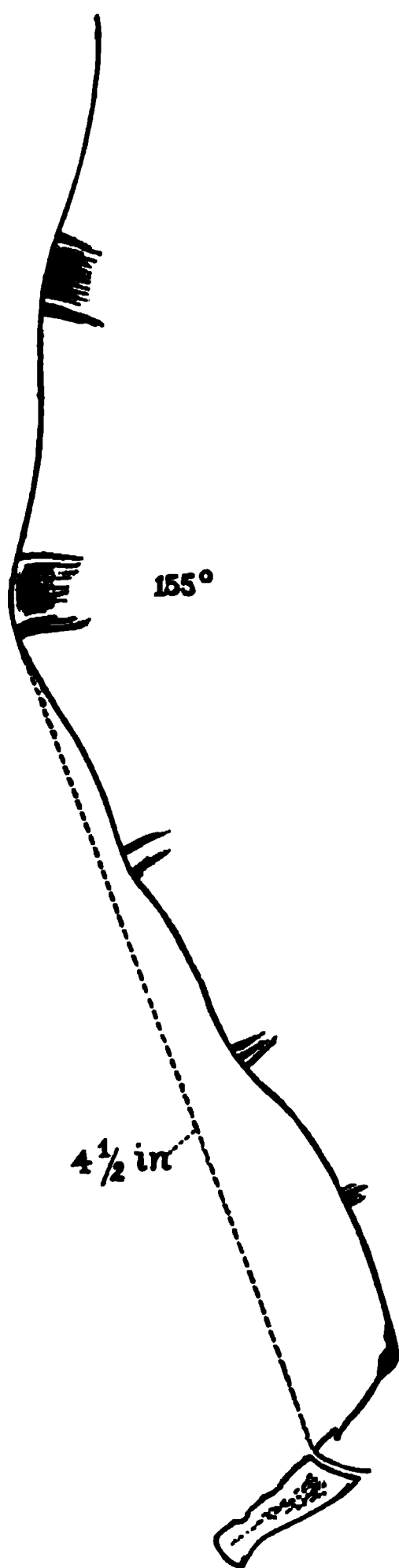
costal cartilage, is $3\frac{1}{2}$ inches long. It has the characters of an ordinary 12th rib. The corresponding rib on the left is barely $1\frac{1}{2}$ in length; its head is large, and very irregular in shape. The 13th rib of each side has a levator costæ, and they both receive the whole of the costal insertion of the quadratus lumborum.

The cervical and upper dorsal vertebræ are normal. The 9th and 10th D.V. have demifacets both above and below for the rib-heads. The 11th D.V. has no facets upon the transverse processes; it has demifacets above for the rib-heads, which are in part situated on the pedicles. Its inferior articular processes look almost directly forwards. The 12th D.V. has a complete facet on each side upon the pedicles; its inferior articular processes look forward and outward. The transverse processes are short, and there are well-marked superior, inferior, and external tubercles.

The innominate bones articulate with $2\frac{1}{2}$ segments of the sacrum; these correspond to the 26th, 27th, and 28th vertebræ. The main attachment is to the 26th, which thus constitutes the '*V. Fulcralis*' of Holl (2), which he finds to be most commonly the 25th.

The sacrum consists of 5 bones: the upper $2\frac{1}{2}$ enter into the formation of the auricular surfaces. The depressions upon the surface for the attachment of the sacro-iliac ligaments, described by Prof.

A. M. Paterson (3), are three in number; the first, corresponding to the 26th vertebra, being large and deep, its floor upon the right side being perforated so as to establish a communication with the neural canal. The transverse processes of the first sacral vertebra are prominent. There is no 'sacral



notch.' The last segment has the appearance of a first coccygeal vertebra, which has become ankylosed to the sacrum. The promontory is formed by the junction of the last lumbar vertebra with the sacrum; it forms an angle of 155° . The sacral curve is chiefly in the lower part of the bone, being formed by the bending forward of the 5th segment. The sacral index is $\frac{100 \times 4\frac{1}{4}}{4\frac{1}{2}} = 94.4$.

The coccyx consists of 3 segments, firmly united into one bone, the last bearing a small nodule, representing the centrum of a fourth vertebra. The first of these segments has the characters of an ordinary 2nd coccygeal vertebra, the 2nd and 3rd segments of the typical 3rd and 4th. The bone articulates by a movable joint with the sacrum.

The coccyx, according to Steinbach,¹ consists in most cases in the male subject of five vertebræ. It is not necessary, therefore, to look upon this case as one in which an additional vertebra has been 'intercalated.' To use Topinard's (4) terms, the specimen is one in which it may be presumed that 'compensation' has occurred, rather than that there is any 'excess' of vertebral elements.

The number of coccygeal vertebræ being reduced by the first having been assimilated with the sacrum, this has been 'compensated' for, by the first sacral vertebra having been liberated to form a sixth lumbar.

The 13th ribs would, if the case were regarded in this light, arise from the persistence and growth of the cartilaginous rudiment which has been shown to be normally present in connection with the first lumbar vertebra of the embryo, its development having been influenced probably by the increased length of the lumbar region.

According to Rosenberg's (5) theory, the case would be an instance of atavism, and comparable with the normal condition in the Gibbon.

Rosenberg believes that there is a tendency in the development of the human race towards shortening of the vertebral

¹ According to E. Steinbach, there are in most instances 5 coccygeal vertebræ in the male, 4 or 5 with about equal frequency in the female.

("Die Zahl der Caudalwirbel beim Menschen," Diss., Berlin, 1889.)

column, and that our descendants in the remote future will be possessed normally of eleven instead of twelve ribs.

Comparing the case with Kölliker's (6) hypothesis, that the 26th spinal segment is the one with which the ilium is primitively and primarily connected in the embryo, and that subsequently a forward movement of the pelvis upon the vertebral column takes place, it would seem that this shifting forwards of the lower extremity upon the vertebral axis had been arrested, and the ilia had remained attached principally to the 26th vertebra.

Welcker and Holl, however, state that the 25th is the primitively first sacral, and in that case the specimen would indicate that a shifting backwards of the pelvis had occurred, and not an arrest of the forward movement, which, it is assumed in the former theory, takes place in the normal development of the individual.

The high bifurcations of the aorta and common iliac arteries, which correspond respectively to the upper border of the 24th vertebra, and the disc between the 24th and 25th vertebræ, and the formation of the lumbar and sacral nerve plexuses described below, are in favour of the backward movement of the pelvis (should it be granted that this has taken place) having occurred subsequently to the development of the vessels, which have retained their original position with respect to the vertebral column.¹

The apparently high bifurcation of the aorta and common iliac arteries will be seen to correspond very closely with the typical, if we regard the 6th lumbar as the true *first sacral* vertebra.

The common iliac veins united to form the inferior vena cava, at a point slightly above the middle of the 5th lumbar vertebra.²

The cervical and upper part of the brachial plexus were, as far as I can remember, formed in the usual way. The anterior primary divisions of the 1st thoracic nerves formed with the 8th cervical the lower primary cord of the brachial plexus, and

¹ I am informed by Dr A. Robinson that the aorta in the mammalian embryo normally bifurcates opposite the 5th L. V.

² From the left common iliac vein a large communicating vessel passed upwards to join the left renal vein, just external to the junction of the left spermatic vein with that vessel.

supplied a small branch to the first space. The 2nd intercostal nerve on each side passes upwards over the 2nd rib to the first interspace; it sends a small branch to its own space, which takes the usual course of the main nerve.

The 12th thoracic nerve of each side, running forward in the abdominal wall from the space between the 12th and 13th ribs, gives no iliac branch.

Five nerves enter into the formation of the lumbar plexus on each side. These are the 21st to the 26th spinal nerves inclusive; or, regarding the 20th vertebral segment as the 1st lumbar vertebra, carrying two lumbar ribs, the 1st to the 5th lumbar nerves.

Distribution of the spinal nerves, with their relation to the vertebral column.

FIG. 3.

| Left Side. | | | | | | | | | | | | Right Side. | | | | | | | | | | | | | |
|------------------|----|----|----|----|----|------|----|--------|----|----|----|-------------|------------------|----|----|----|----|----|------|----|--------|----|----|----|----|
| T. Lumbar. | | | | | | | | Sacral | | | | C. | T. Lumbar. | | | | | | | | Sacral | | | | C. |
| V ¹ . | 12 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | V ¹ . | 12 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 |
| S.N. | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | S.N. | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| L.D. | 20 | | | | | n.f. | | | | | | | L.D. | 20 | | | | | n.f. | | | | | | |
| I.H. | | 21 | | | | | | | | | | | I.H. | | 21 | | | | | | | | | | |
| I.L. | | | | | | | | | | | | | I.L. | | | | | | | | | | | | |
| G.C. | | 21 | 22 | | | | | | | | | | G.C. | | | 22 | | | | | | | | | |
| E.C. | | | 22 | 23 | | | | | | | | | E.C. | | | 22 | 23 | | | | | | | | |
| O. | | | | 23 | 24 | | | | | | | | O. | | | 22 | 23 | 24 | | | | | | | |
| A.C. | | | | 23 | 24 | 25 | | | | | | | A.C. | | | 22 | 23 | 24 | 25 | | | | | | |
| L.S. | | | | | | 25 | 26 | | | | | | L.S. | | | | | | 25 | 26 | | | | | |
| S.G. | | | | | | 25 | 26 | | | | | | S.G. | | | | | | 25 | 26 | | | | | |
| I.G. | | | | | | 25 | 26 | 27 | 28 | | | | I.G. | | | | | | | | | | | | |
| E.P. | | | | | | 25 | 26 | 27 | 28 | | | | E.P. | | | | | | | | | | | | |
| I.P. | | | | | | 25 | 26 | 27 | 28 | 29 | | | I.P. | | | | | | 25 | 26 | | | | | |
| S.S. | | | | | | | | | 28 | 29 | | | S.S. | | | | | | | | | | | | |
| O.I. | | | | | | | | | 28 | 29 | | | O.I. | | | | | | | | | | | | |
| P. | | | | | | | | | 28 | 29 | | | P. | | | | | | | | | | | | |
| S. | | | | | | | | | | | 30 | | S. | | | | | | | | | | | 30 | |
| C. | | | | | | | | | | | | 31 | C. | | | | | | | | | | | | 31 |
| V ² . | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | V ² . | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |

V¹ in the upper line represents the corresponding vertebra of each spinal nerve (S.N.) figured below, arranged according to the different regions in the normal vertebral column.

All those vertebrae which are to the left of the double line between the 26th and 27th spinal nerves are presacral.

The sacrum is formed by the 26th-30th vertebrae inclusive: the numbers representing these are seen in the line V² at the bottom of the table.

The names of the nerves are indicated by their initials in the columns to the left.

The right sacral and pudendal plexuses are not represented, the innominate bone having been disarticulated on that side, in the ordinary course of dissection, before the anomaly in the formation of the column was recognised.

On looking at the table, fig. 3, it will be seen that the

lumbar, though almost normal as regards its upper part, is taken as a whole of the low form or 'post fixed' type of Sherrington.



The ilio-inguinal nerve is absent on both sides. The 5th lumbar nerve (25th spinal nerve) is divided between the lumbar and

sacral plexuses on each side, thus constituting the 'furcal nerve' of v. Jhering (7).

The lumbo-sacral cord¹ derived from the 25th and 26th spinal nerves on the left side joins with the 27th, 28th, and 29th to form the great sciatic nerve, the external popliteal deriving fibres from the 25th to the 28th inclusive, the internal popliteal from the 25th to the 29th.

The pudic nerve is derived from the 28th and 29th spinal nerves, which issue from the 2nd and 3rd sacral foramina.

As the internal popliteal nerve receives a branch from both the 28th and 29th, each of these nerves is common to both the sciatic and the pudic plexuses. The 29th spinal nerve passing through the 3rd sacral foramen, being the last root of the great sciatic nerve, would be regarded as the 'bigeminate': it is, however, a small branch; and the first root of the pudic nerve being derived from the 28th, I am inclined to look upon this as the true 'nervus bigeminus.' Supposing the 6th lumbar vertebra to be a liberated sacral, this nerve, the 28th, would represent the 3rd sacral, viz., that nerve which in the human subject has been found by Eisler (8) and Prof. Paterson most commonly to form the bigeminate. On the other hand, the sciatic nerve receiving a branch from the 29th, corresponds with the low position of the 'furcal nerve,' which is formed by the 25th spinal nerve.

A nerve issues on each side from the fourth anterior sacral foramen, and communicates with another coming forward through the coccygeus muscle, between the sacrum and coccyx. These two nerves are the 30th and 31st spinal; and regarding the last sacral vertebra as the 1st coccygeal, which has become ankylosed to the sacrum, they would represent the 5th sacral and 1st coccygeal nerves.

Coming through the coccygeus muscle by the side of the first segment of the movable coccyx, there was apparently upon the left side a 32nd spinal nerve. This, examined microscopically, showed no definite nerve structure.

Schlemm, in examining seven cases, found two coccygeal nerves

¹ Prof. Paterson found in 23 dissections that the n. furcalis was derived from the 4th lumbar nerve in 19; from the 5th nerve in 5. "Origin and distribution of nerves to lower limb," *Jour. of Anat. and Phys.*, vol. xxviii. p. 87.

on both sides, in one instance, and on one side only in another case.

Rauber has also described vestiges of a second and even a third pair of coccygeal nerves as normally present in the bundles of medullated nerve fibres normally contained in the *filum terminale*.

The formation of the plexuses, and their relation to the vertebral column, resembles to a certain extent cases which have been reported by Prof. Birmingham (9) and Paterson, and, like them, these relations tend to favour the view that cases of numerical variation in the number of vertebræ forming the different portions of the column are due to variation in the position of the attachment of the extremities to the trunk, and not to the interpolation of an additional segment in the particular region in which the extra vertebra is found.

I have laid considerable stress upon the nerve relations of this case, as it seems probable that, as stated by Goodsir (10), "the nervous elements of the limbs appear, as in other parts of the vertebrate animal, to indicate most distinctly the morphological constitution of the sclerous elements."

Variations in the number and position of the segments forming the vertebral column appear to be by no means infrequent. According to Tenchini (11), in eighty cases which he examined, he encountered eight which he classified in the following manner:—

In excess 3,—34 vertebræ.

In default 3,—32 vertebræ.

He supports the view that instances occur in which variations in one portion of the spinal column are not always accompanied by a compensating excess or diminution in another. His cases, though numerous, are, however, unaccompanied by any detailed reports. It will be interesting to hear what light further dissections will throw upon the question.

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ON THE STRUCTURE OF CROSS-STRIATED MUSCLE,
AND A SUGGESTION AS TO THE NATURE OF
ITS CONTRACTION. By W. M'DOUGALL. (*From the
Physiological Laboratories of St Thomas's Hospital and the
University of Cambridge.*) (PLATES XVI.—XXV.)

(Continued from page 441.)

Interpretation of the Appearances of Leg Muscles of Dytiscus.

I shall first offer what seems to be the only possible interpretation of the appearances, in terms of our working hypothesis,—an interpretation which, if the truth of the hypothesis be assumed, seems to consist merely of necessary inferences as to the structure of the muscle columns drawn from the changes in shape which they exhibit during contraction; and I shall then bring forward further observations and arguments in support of it.

If the structure of the lamellar muscle columns is similar to that which I have described as obtaining in the wing sarcostyles, *i.e.*, if the muscle column consists of a series of membrane-bounded chambers filled with fluid, and separated from one another by transverse inextensible septa, of which the lines α and their bright borders are the optical expression, and if in each of these segments or sarcomeres there be at the levels γ β γ three transverse extensible elastic septa, of which that at β is less readily extensible than the others, then if, by any force, the septa α are approximated to one another, all the changes in shape of the muscle column that I have described must follow. For this sarcomere in the uncontracted state is a rectangular chamber, of which the depth measured in the long axis of the fibre (*i.e.*, the distance between the lines α in stage A) is $5\ \mu$ and the thickness is about $1.4\ \mu$, and the width measured in the radial direction is not the same in all columns, but varies between $15\ \mu$ and $30\ \mu$; the second dimension is given by the intervals at which the longitudinal lines of sarcoplasm occur on the mid-line of the surface of a fibre in stage A (see photo. 19).

and the last measurement is made on transverse sections of living fibres. These sarcomeres are joined together in longitudinal series to form the muscle column. It is obvious that if the sarcomere is changed in shape by the approximation of the septa α and a bulging of its side walls, the volumes of the successive solid figures which it forms vary with the area of the cross-section parallel to its smallest side, *i.e.*, with the area of the end which appears at the surface of the fibre, and which is $5\ \mu$ by $1.4\ \mu$ in stage A. For any change in volume due to bulging of these small end-walls is, in a chamber of this shape, so small a part of the whole change that it is negligible. But, according to the hypothesis as to the structure of the sarcomeres, each is

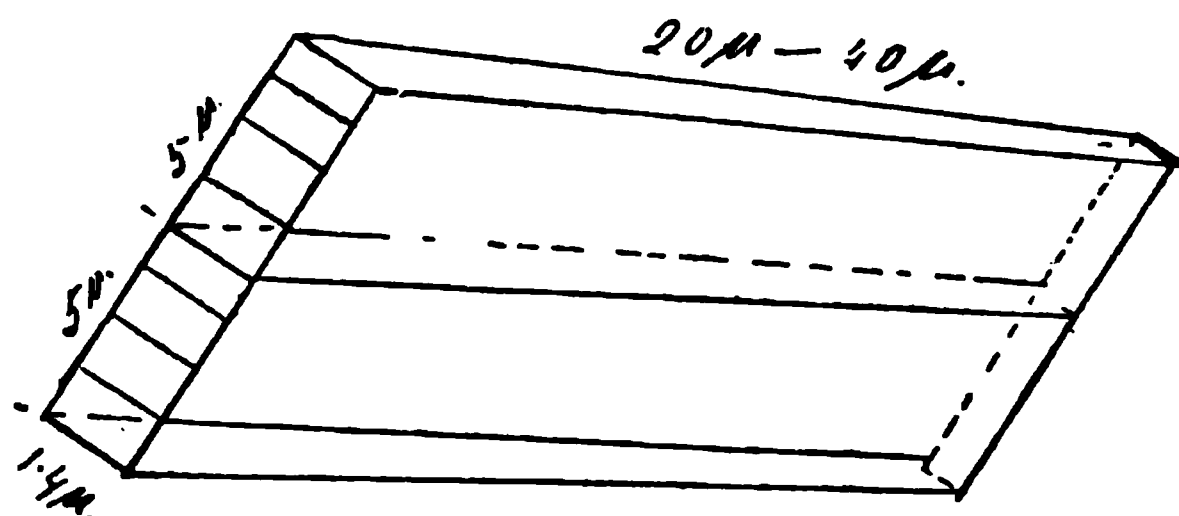


FIG. 14.—Diagram of two sarcomeres fully extended.

divided into four equal parts by transverse septa at $\gamma\ \beta$ and γ , and the area of the small end at the surface is divided into four smaller areas, of which each is $1.4\ \mu$ long and $\frac{5}{4}\ \mu$ broad (*cp.* fig. 14). Now, a rectangular surface whose sides may become curved outwards as arcs of circles, with a corresponding drawing together of its ends without change of area,¹ is one of which the ends are to the sides as 8 to 7, and in any rectangular area of which the length of the sides is a smaller fraction of the length of the ends than $\frac{7}{8}$, such a curving of the sides results in a diminution of area. Now, the ends of the four small areas into which the ends of the sarcomeres at the surface of the fibre are divided by the lines $\gamma\ \beta\ \gamma$ are to the sides of these areas as $1.4\ \mu$ to $\frac{5}{4}\ \mu$, and therefore such a change of shape without alteration of the lengths of the walls must in their case result in a

¹ This, again, is not strictly accurate: there must be a variation in area, but so slight as not to affect the argument.

diminution of area. Since, then, the volumes of the chambers of the sarcomere vary with these areas, any force tending to bring together the septa α , by causing the fluid contents to press upon the side walls, will, just as in the case of the chambers of the wing sarcomere, make the segments of these bulge as arcs of circles, and the resulting tendency to diminution of volume will be compensated by the stretching of the elastic septa $\gamma \beta \gamma$. It will suffice to point out, without following out the details of the process, that the conditions of these sarcomeres are quite similar to those which obtain in the wing sarcomeres, and that as the septa α , the ends of the sarcomeres, come nearer and nearer together, there will result a series of changes similar to those described in the contracting wing sarcomere, namely, the stretching out of the septa $\gamma \gamma$ with the obliteration of the constrictions caused by them, and the rolling out of the side walls on one another at α , and in later stages the stretching out of β and the obliteration of the constriction caused by it. So there will be produced the series of changes in the distribution of the sarcoplasm and the outlines of the muscle columns that I have described above.

Further Observations supporting the above interpretation.

If the muscle columns are really hollow lamellar tubules (if the phrase may be used), the structure and arrangement of their parts that I have suggested seems to be the only conceivable one by which the observed changes of shape could be brought about. What is, then, the evidence that the muscle columns are such tubules filled with fluid?

In the first place, the complete analogy in the cycle of changes during contraction between these muscle columns and the wing-muscle sarcostyles indicates that they are essentially similar structures; and the observations, that I have recorded above, on the structure of the wing-muscle sarcostyles, leave no doubt in my own mind that they are hollow tubules, with membranous walls.

Secondly, there is a certain amount of direct evidence of the existence of membranous walls to the muscle columns. Although I have not succeeded in showing the stained wall in photographs of transverse sections, I have seen in well-stained

sections a thin dark line marking the plane of separation between the sarcoplasm and the muscle columns; and in preparations made by partially disrupting by pressure transverse sections of fibres fixed with chromic acid and stained with logwood, I have occasionally found isolated parts of muscle columns presenting their transverse section to view; such a transverse section is bounded by a thin darkly-stained line, which seems to be the section of the wall of the column, though it might possibly be due to a layer of adherent sarcoplasm.

Isolated muscle columns stained with logwood (*cp.* photos. 21, 24, 25, and 30) appear faintly stained in all their length, and that the staining is of the surface only, as in the case of the wing fibrils, is shown by the fact that no staining of the substance forming the thickness of the columns can ever be seen in transverse or longitudinal sections of them stained with logwood.

Photos. 21, 24, and 25 show that after fixing with chromic acid the surfaces of the muscle columns are longitudinally wrinkled: I shall show below that this wrinkling is due to the shrinkage caused by the chromic acid. Now, if the muscle columns be slips of homogeneous substance comparable to slips of gelatine, there is no obvious reason why shrinkage should cause this wrinkling of their surfaces. But if they be of the nature of membranous tubules, then the abstraction of fluid from their interior, which undoubtedly results from the action of the chromic acid, may well cause a longitudinal wrinkling such as is always produced by it.

It is clear that, just as in the case of the wing sarcostyles, there must be longitudinal foldings of the walls of the extended sarcomere to allow the increase in diameter at its equator to be effected, and these should be especially well-marked on the narrow end-walls at the surface of the fibre. When the surface of an extended fibre is carefully focussed, longitudinal striæ can be made out on these end walls, and it seems probable that they are the expression of such foldings.

When the wing sarcostyle is treated with strong alcohol, it can be seen to shrink at the middle part of each sarcomere, causing the discs α to project prominently at the edge. This is presumably due to the dehydrating action of the alcohol on the watery contents of the sarcomere. Strong alcohol has just the

same effect upon the segments of these muscle columns. To this point I shall have to return below.

Thirdly, a strong argument in favour of this view of the structure of the muscle columns may be based on general considerations. The muscle columns are the parts which support the weight of a heavy body attached to a muscle (in the contracted if not in the relaxed condition), and a strip of muscle 1 sq. cm. in cross-section can lift a weight of nearly 10 kilos. (7. S. 64). The substance of the muscle columns, which forms only a part of the cross-section, is then capable of resisting a very considerable pull, and some such structure as that which I am endeavouring to establish for the muscle columns is the only one compatible with their known properties. For, at the same time they are the seat of very rapid and complex chemical changes, they are capable of resisting a very considerable longitudinal tension, of undergoing a rapidly-alternating shortening and elongation amounting to more than 50 p.c. of their length, with very definite changes in their configuration, and they retain their form under all sorts of violent stresses. We may, of course, escape the conclusion forced upon us by this argument by supposing that the substance of living cells is of a nature different to anything known outside the living body. We may, then, attribute to it any combination of properties which seems most convenient: for example, we may call it 'semi-solid,' and attribute to it the properties of a perfect fluid and a perfect solid. But this seems to be a giving up of the whole problem; and we have no right to assume this position while it is possible to offer any satisfactory explanation of the facts in terms of our working hypothesis.

Fourthly, Kühne has shown (8, p. 322) that after breaking up the substance of living muscle very finely, there may be expressed from it a considerable quantity of liquid muscle plasma; and it is almost certain, as will be generally admitted, that this formed, in the recent state, a part of the muscle columns.

I have made a large number of pairs of preparations in the following manner:—A small slip of the leg muscle of the beetle was taken from one side of the body and pinned out and fixed by formaline in a condition of complete extension; the corresponding slip was taken from the other side of the body of the

same beetle, and was thrown free into formaline, in which it became fixed in a contracted state, usually a late C or the D stage. Transverse sections were then cut with the freezing microtome from both pieces, and either sections from the middle parts of each were mounted, or the whole of each was cut into sections, and the sections from the middle part and from either end were mounted in three separate groups. I then carefully measured the lengths of the radial sections of the muscle columns in a number of sections on each one of the pairs of slides so obtained, so as to find their average length, and also measured those of smallest and of largest radial length. Then, on comparing the lengths so observed with the lengths similarly measured on the other slide of the pair, it was not possible to detect any constant difference between the lengths of the radial areas (*i.e.*, in the width of the muscle columns) in the sections of the fibres in the contracted and in those in the extended states. The increase in the area of the cross-section of a fibre which accompanies contraction seems then to be wholly due to the increase in width of the muscle columns, the central core being lengthened out in the cross-section, when it has a simple linear character, and becoming more complex and branched when it has the $>—<$ shape, or some modification of it, in the extended state. The columns, then, do not increase in width during contraction, but only in thickness; and this fact seems to me to support very strongly the view of their structure adopted here. For if they were bundles of smaller elements, the sarco-styles of Schäfer, or of fibrillæ, as maintained by v. Kolliker and Rollett, or were of contractile protoplasmic substance, then it might fairly be expected that during contraction each diameter of the cross-section of the columns should be increased in proportion to its length. But if the structure of the columns be anything like that ascribed to them above, then, as I have already pointed out, the bulging outwards of the side walls is almost certainly due to a fluid pressure exerted upon them from within the columns, be the origin of this pressure what it may. The tendency to increase in thickness must then be greater than the tendency to increase in width in the same proportion, as the area of the side walls is greater than the area of the narrow end-walls of the segments of the columns.

This observation also supports, in some measure, the view of the inextensible character of the α septum and the interpretation of its apparent increase in width during contraction that was given above. For the fact that there is no perceptible increase in its long axis during contraction seems to render probable the view that there is none in its short axis, and that it really is a practically inextensible membrane. Then, since the α discs of the wing-muscle fibrils are, as we have seen, analogous in so many respects to the α septa of these muscle columns, the view of the structure and function of the latter set down above also derives support from this observation.

Some difficulties.

There are two closely connected facts in the histology of these muscle fibres which are difficulties in the way of the acceptance of this view of the structure of the muscle columns:—firstly, the narrow radial ‘areas of Cohnheim’ of the cross-section have often been represented broken up into smaller areas; and secondly, there may easily be teased out from the fibres after treatment with strong alcohol or chromic acid, fine thread-like strips, the so-called fibrillæ. The former fact may, I think, be readily explained. Van Gehuchten (3) has pointed out and illustrated by drawings how rough treatment of fibres destroys the regularity of the appearance of the cross-section, causing the narrow radial ‘areas of Cohnheim’ to be replaced by irregular polygonal areas. My own preparations also indicate that, the more successful the preparation, the more regular is the appearance of the cross-section and the fewer are the number of ‘areas of Cohnheim’ which are interrupted in their course from the core to the periphery of the fibre. In sections cut with the freezing microtome from living or steamed fibres, or from fibres fixed with formaline and carefully handled, it is unusual to see any section of a muscle column which does not run uninterruptedly from the core to the periphery. Remembering that the radial walls of the muscle columns are delicate membranes between layers of fluid or viscid substance, it is easy to see that pressure upon the side of the fibre may cause them to deviate from the straight course. In many transverse

sections it can be seen that the lines of these walls run in a wavering or zigzag manner, though remaining distinct from one another, and any increase in this irregularity must cause them to come into contact with one another at some points, and so cause the 'areas of Cohnheim' to appear to be broken up into smaller areas.

The splitting up of the columns into fibrillae seemed at first more difficult to reconcile with the view of the structure of muscle that I am trying to establish. For the existence of the fibrillae, as upheld by von Kölliker (5), in the living muscle columns, seems incompatible with the presence of transverse septa tying the walls together. Rollett, in treating of this question, says:—"Aus der vorangehenden Darstellung ergibt sich, dass die Praeformation der Muskelsäulchen im lebenden Muskel eine streng zu erweisende Thatsache ist. Anders verhält es sich mit den Fibrillen. Die Annahme, dass diese letzteren praeformirt sind, kann sich vorläufig nur auf Wahrscheinlichkeitsgründen stützen" (2. II. p. 28). He points out that the breaking up into fibrillae after treatment with alcohol or chromic acid, and the longitudinal striæ on the muscle columns, are the only facts in favour of the view. In a great number of careful cross-sections which he made of living muscle of different kinds, he found no indication of the existence of fibrillae, though in some cross-sections of muscles treated with alcohol there were such indications. Retzius (4) is led by his preparations to believe in the existence of the fibrillae, but admits that an interfibrillar substance has never been demonstrated. Schäfer (1), who first put forward this 'sarcomere view' of the structure of muscle, definitely gives up the fibrillae. His view of the structure of the muscle columns differs from mine in that he believes that each one consists of several sarcostyles strictly analogous to those of the wing muscles, placed side by side. But his reasons for adopting this position are very slight; they consist in the observation of certain oblique irregular faint lines crossing the 'areas of Cohnheim' in preparations which had been more or less deformed.

On carefully comparing the thickness of muscle columns fixed with chromic acid with their thickness in living fibres, it is evident that they are laterally shrunken to little more than half their normal thickness,—cp. photos. 22 and 35 with photos. 23 and 36,—just as is the case with the wing fibrils, and there can be little doubt that a similar shrinkage occurs in their radial width. The length of the segments is practically unaffected. Photographs 21 and 24 show that the shrinkage is accompanied by the appearance of longitudinal wrinkles or folds in the walls of the columns, and photo. 36 shows that these foldings are very fairly regular and of considerable

depth, so that both surfaces of a column are marked by closely set, parallel, longitudinal grooves. Remembering that the muscle columns are, after fixation with chromic acid, very thin brittle lamellæ, it seems not unlikely that these grooves may determine the breaking off of thin strips, the so-called fibrillæ. That this is actually the case is, I think, proved by the effect of adding formic acid to the chromic acid solution used for fixing. Formic acid in weak solution causes the muscle columns of living or steamed fibres to swell out rapidly. If formic acid be added to the .2 per cent. chromic acid solution until there is present from 1.5 to 2 per cent. of formic acid, and fibres be fixed by immersion in this mixture for twenty-four hours, the shrinkage caused by chromic acid alone may be exactly compensated for. In a longitudinal view of fibres it can be seen that the columns retain their normal thickness (photo. 20), and in transverse sections the plane of separation between sarcoplasm and columns is an even line, just as in photo. 35, and muscle columns isolated by teasing show no longitudinal wrinkles (photos. 26 and 30). In preparations of fibres fixed with chromic acid and teased there always occur numerous fibrillæ as well as parts of isolated columns, while in teased preparations of fibres fixed with the chromic and formic mixture there occur isolated muscle columns (photos. 26 and 30), but in the more successful preparations no fibrillæ, and in less successful only a few fibrillæ.

To the question "Are there any smaller longitudinal elements making up the muscle column?" I shall return, but I think that it now appears highly probable that the muscle column is strictly analogous in structure and function to the sarcostyle of the wing muscle, and may also be properly called a sarcostyle, and that its segments are the contractile units, and may be called sarcomeres in the same sense as those of the wing-muscle sarcostyles.

I have not been able to obtain direct evidence of the existence of the septa B and δ in the sarcomeres of this type of muscle; and the probability of their actual existence must, for the present, remain such as is afforded by the inferences drawn above from the changes in shape exhibited by the sarcomeres during contraction, and by the close analogy in all other points

between these sarcomeres and those of the wing muscles of insects, and of the skeletal muscles of the crayfish; for I shall bring forward below direct evidence of the presence of such septa in the latter muscles.

Comparison of the above account of the Leg Muscles of Dytiscus with the descriptions of recent Observers.

Rollett (2) gives diagrams, based upon the study of many kinds of insect muscles after treatment with reagents, representing the typical forms of cross-striation. And since, as he points out, what appears dark at one focus appears light at a slightly deeper focus, and *vice versa*, he gives two diagrams side by side, representing two slightly different foci.

Fig. 15 is a rough copy of his first diagram (2.I. fig. 5 A) of the typical cross-striation in the extended state. It will be seen that this corresponds to the appearance that I have described as characteristic of stage B in the leg muscle of *Dytiscus*, the three transverse rows of dots of sarcoplasm being optically fused to the three bands J h J, the line α being doubled, as it always is when slightly out of focus. Rollett's third diagram (2.I. fig. 5 C), of a more contracted state of the fibre, seems to represent what I have called stage C, the sarcoplasm being mostly accumulated opposite the

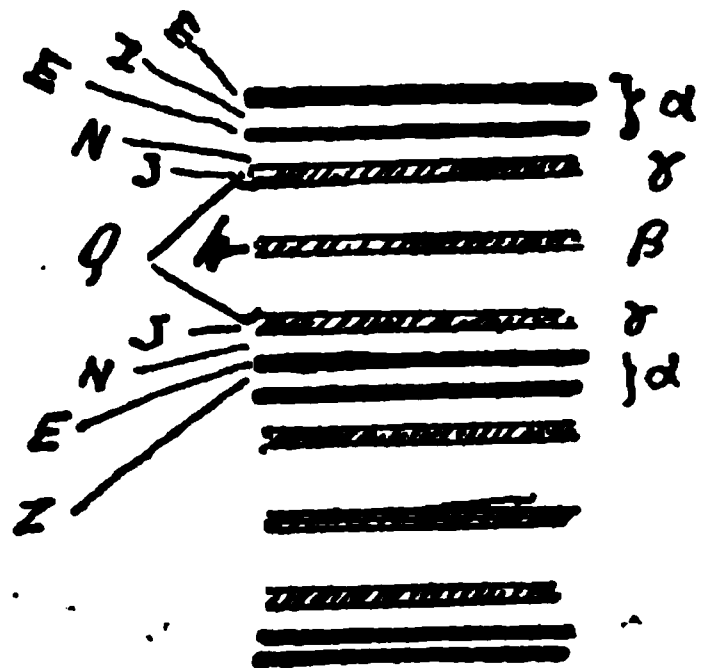


FIG. 15.
Rollett's lettering on the left, my own on the right.

middles of the sarcomeres, through the action of alcohol, and the longitudinal alternation of muscle columns and planes of separation with the sarcoplasmic accumulations not being distinguished, but the masses of sarcoplasm being optically fused to dark transverse bands. Rollett describes as very common in acid and gold preparations a distribution of the sarcoplasm such as I have described as characteristic of stage C (photo. 29). He calls the rows of dots of sarcoplasm at α 'Knotenreihen' of the first order, and those at β 'Knotenreihen' of the second order. He mentions that Retzius has described 'Knotenreihen' of a third order, alternating with these. These seem to be the sarcoplasmic accumulations at $\delta \delta$ in stage B. (Cp. plates in which the appearance characteristic of stage B is represented by Retzius (4). He adds that in specially good preparations he has himself seen them, and that in such cases the 'Knoten' of the first and second orders are smaller than when those of the third order are absent. But he regards the appearance as very rare. This probably results from his having

thrown whole beetles into his reagents and separated the muscles afterwards, when they are naturally found fairly well contracted in almost all cases.

As the result of his study of the cross-striation of acid and alcohol preparations, Rollett concludes that in the living state the muscle columns and the lines of sarcoplasm between them run continuously through the length of the fibre without variations in thickness, and that the cross-striation is determined by differences in the optical qualities of the muscle columns at different levels. He believes that the regular thickenings on the muscle columns, and the consequent accumulation of the sarcoplasm in 'Knoten' at the intermediate levels, is entirely a result of the action of acid, the columns swelling more at certain parts than at others (2.I. S.48). I have no hesitation in saying that this conclusion is very far from true, since, as I have shown above, the thickenings on the muscle columns and the accumulations of sarcoplasm are visible in the living fibres, and during contraction go through a perfectly definite and regular series of changes.

Van Gehuchten (3) has given a great number of drawings of the appearances of different kinds of muscle after treatment with alcohol or acids. I have already pointed out that strong alcohol causes the sarcomeres to shrink at their middles, presumably by extracting water, so that the thick resistant septa α remain the broadest parts of the sarcostyles. Alcohol therefore tends to make the sarcoplasm accumulate at the levels intermediate to the lines α : this is often found to be the result, though the action is very inconstant,—the normal distribution for the state of contraction being sometimes preserved. Van Gehuchten's drawings faithfully represent these effects of alcohol: when the sarcoplasm is accumulated between the shrunken sarcomeres he speaks of 'batonnements' on the longitudinal strands of his 'contractile network,' and believes that they are produced by a precipitation of matter on these parts from the fluid 'enchylema.' Acids tend to cause the sarcomeres to swell (as I have already mentioned), and the sarcoplasm to be displaced from between the middles of the sarcomeres and to accumulate at the levels of the discs. As van Gehuchten points out, the action of acids is very inconstant, and seems to vary, as might be expected, with the preliminary treatment. Thus, for instance, Melland (9) seems to have put the muscle into lemon juice always in the first stages of his gold preparations, with the result, as might be expected, that the sarcoplasm was very frequently accumulated at the levels α .

I have made many preparations by the ordinary acid and gold methods. In some cases the normal distribution of the sarcoplasm is maintained, and I believe that all the abnormal appearances are readily explicable as the result of the swelling action of the acid on the muscle columns in different stages of contraction. For example, one of the most peculiar appearances that I have come across in such preparations was due to the

arrangement of the sarcoplasm in dumb-bell shaped masses at the levels α . This was in a preparation very much swollen by formic acid: it seems to have been produced by the bulging out of the sarcomeres driving the sarcoplasm to the levels α , and the subsequent swelling of the thick septa α themselves; the accumulations of sarcoplasm being nipped between the ends of the expanding septa (see fig. 16). Van Gehuchten's and

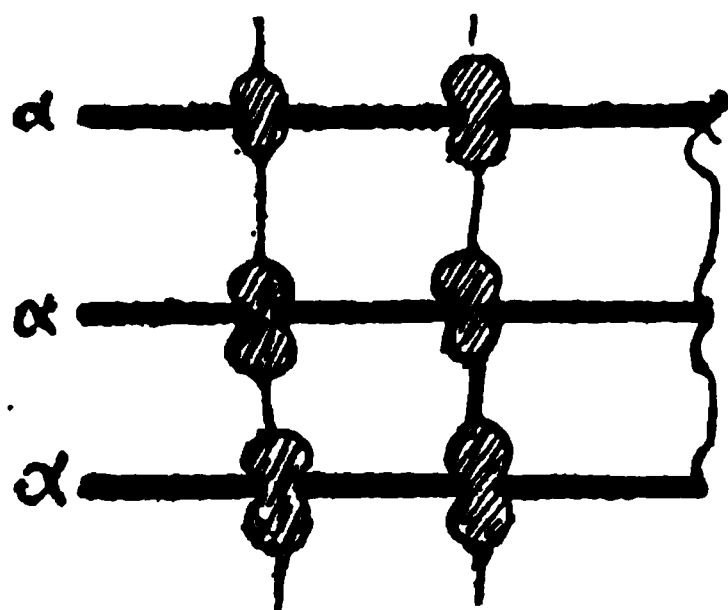


FIG. 16
(cp. photo. 31).

Rollett's drawings represent faithfully many of the various appearances produced by these reagents.

There can be no doubt that the transverse line generally known as 'Krause's membrane,' 'stria of Amici,' or 'Dobie's line,' corresponds to the line formed at the level α by the optical fusion of the lines α , and the sarcoplasmic accumulations between them

at the same level. But I have preferred to use a concise and consistent nomenclature for the different parts, rather than to make use of names given to parts somewhat loosely before they had been accurately distinguished and defined.

I have never been able to understand exactly what is meant by the term 'Nebenscheibe' or 'accessory disc,' as used by various authors. It is the name generally given to transverse lines described as lying on either side of 'Krause's membrane,' and of extreme inconstancy in appearance. It seems probable that they are due to the optical fusion of the sarcoplasmic accumulations at γ and γ in fibres in stage B of contraction.

On the Structure of the Somatic Muscles of the Frog and Mammal.

Before the above conclusions as to the structure of the leg muscles of the beetle can be accepted as well established, it must be shown that the muscles of other and widely different animals have an essentially similar structure. For it seems, '*a priori*,' highly probable that all cross-striated muscles are funda-

mentally of the same nature. I have therefore examined the muscles of the frog and rat, using the same methods as in my previous investigations. I have used the 'sartorius' and the sterno-cutaneous muscles of the frog, choosing the former because, owing to the simple longitudinal arrangement of its fibres, the degree of their contraction can be readily recognised, and the latter, on account of their small size; and in the case of the rat, I have used the thin sheets of muscle in the wall of the belly. I found that the appearances presented by surface views, or longitudinal sections, or isolated muscle columns are so nearly identical in the muscles of these two animals that one description of them, and one series of photographs illustrating the appearances of the various stages of contraction, will apply equally well to both. The appearances presented by the living muscle fibres of the frog or mammal may be shortly summed up by saying that they are identical with those presented by the fibres of the leg muscles of *Dytiscus*. In each of the stages of contraction, A, B, C, D, as determined both by the length of the whole muscle and by the measurement of the intervals at which the lines α occur, the fibre presents an appearance identical with that described for the same stage of the leg muscle of *Dytiscus*, and the transition may be traced from a part in one stage to neighbouring parts of the same fibre in other stages of contraction in exactly the same way.

Photos. 37, 38, 42, 44, some of which were taken from fibres simply fixed by the application of a jet of steam to the cover-glass, and others from fibres fixed with formaline and stained with logwood, illustrate all the stages of contraction from A to D. As will be noticed on comparing these photographs with the photographs taken from fibres of the leg muscle of *Dytiscus* in the corresponding stages of contraction, the structure of the muscle of the frog and of the rat is on a smaller scale than the other, and this is the only difference that is presented in the longitudinal aspect of the fibres by the striated substance of the living muscles of these members of these widely separated classes. In the fully extended state of the frog's and mammal's muscle, *i.e.*, stage A, the lines α are at intervals of only $3\ \mu$ in the great majority of the preparations that I have made, while in the *Dytiscus* muscle they are at intervals

of $5\ \mu$; and in all the stages of contraction of the muscle of the frog and rat, they are at correspondingly smaller intervals. In the fully extended state, the longitudinal lines of sarcoplasm occur at intervals of about $1\ \mu$ on the mid line of the surface of the fibre, and in stage B the planes of separation of the muscle columns are at slightly greater intervals. The width of the muscle columns is therefore $1\ \mu$, or slightly less. The optical section of each segment of a muscle column in stage A is therefore an area $3\ \mu$ long by slightly less than $1\ \mu$ across, while the corresponding measurements in the *Dytiscus* muscle are $5\ \mu \times 1.4\ \mu$. The proportions are therefore practically identical in the two cases. But, just as the structure is not equally coarse in all fibres of the beetle's leg muscles, so also in the frog and rat there are found occasionally fibres in which the absolute measurements of the parts are slightly smaller or greater than in the typical fibre of averagely coarse structure. Thus the structure seems to be rather finer than usual in the fibre shown in photo. 37, and rather coarser in the fibres of photos. 41 and 42. But the important fact is, that the proportion of parts to one another is the same in all these fibres, and is the same as in the beetle's leg muscles.

This close correspondence in the appearances presented by the longitudinal aspect of fibres of the frog's and rat's muscle on the one hand, and of the leg muscles of the beetle on the other, having been described and illustrated, it remains to produce evidence of a similar correspondence in other points, and to show that the former muscles consist, like the latter, of lamellar sarcostyles. And though the study of these muscles, and especially of transverse sections of them, is very much more difficult, there is forthcoming evidence on this last point of exactly the same kind as in the case of the beetle's leg muscles.

In the first place, the lines of stained substance in a fibre in stage A are proved, by careful focussing, to be the optical sections of thin planes or sheets of sarcoplasm lying between unstained muscle columns.

Secondly, there may be isolated from fibres fixed with chromic acid, or the mixture of chromic and formic acids, delicate laminae less than $1\ \mu$ thick, which exhibit all the features described above in the isolated sarcostyles of the beetle's

leg muscles. Photos. 40 and 43 are from such laminae, and show the cross-striation characteristic of a late B stage and the C stage respectively.

Thirdly, on cutting with the ether microtome transverse sections of the living muscle fibres frozen in a drop of white of egg, as recommended by Rollett, or of fibres fixed by steam or formaline, it is found that the transverse section presents long, narrow, clear areas, sections of the muscle columns, separated from one another by darker lines, which stain with logwood, and are the expression of the sheets of sarcoplasm between the muscle columns. In sections of frog's muscle fibres these areas radiate occasionally, though rarely, from a central narrow area, so that the appearance of the transverse section closely resembles that of the beetle's leg muscle, but generally the areas run across the whole width of the fibre, or may be arranged in two or more systems of parallel areas (photos. 47 and 49). In transverse sections of fibres of mammalian muscle, the parallel areas are more variously arranged in more numerous systems, each one of the systems being the transverse section of a bundle of lamellar muscle columns packed side by side (photos. 45 and 46). In teased preparations of fibres fixed with chromic acid there occur, besides parts of isolated muscle columns, numerous 'fibrillae,' as in the case of the beetle's leg muscles. The formation of these seems to be due here also to the longitudinal wrinkling of the walls of the muscle columns, produced by the shrinking action of the chromic acid. This wrinkling is shown in photo. 48, which represents part of a transverse section of a fibre fixed with chromic acid. Here, too, it may be obviated by the addition of formic acid to the extent of 2 per cent. to the chromic acid used for fixing the muscle; and from fibres in which this is successfully effected there may be teased out parts of isolated muscle columns without the separation of any fibrillae, while transverse sections show even lines of separation between sarcoplasm and muscle columns.

There can, then, be little doubt that the structure of these muscles is essentially similar to that of the leg muscles of the water-beetle, and that the fibres consist of lamellar muscle columns or sarcostyles embedded in sarcoplasm, and that the segments of the columns or sarcomeres are in every point very

similar to those of the beetle's leg muscles, and closely analogous to the sarcomeres of the insect's wing muscles.

It is necessary to add, that in transverse sections of these muscles, more especially of the frog's, there can sometimes be seen fine lines crossing the narrow areas, the section of the muscle columns, at fairly regular intervals, but these are not lines of sarcoplasm; and though they may indicate that the muscle columns have some kind of longitudinal septa, they cannot be considered to constitute any objection to the view that the lamellar columns are the physiological elements or sarco-styles, in the same sense as the fibrils of the insect's wing muscle. That the true picture of the transverse section of these muscles is not obtained with constancy by all the ordinary methods is not a matter for surprise when we remember that various authors have depicted the transverse section of fibres of the leg muscle of *Dytiscus* even as made up of irregular long ovals, and even more or less polygonal areas (which appearances are undeniably the result of the treatment that the fibres have suffered); and further, that the parts of the muscles of the frog and mammal are scarcely more than one-half as large as the corresponding parts of the beetle's leg muscle, and are probably correspondingly more delicate and more easily deformed.

On the Structure of the Skeletal Muscles of the Crayfish
(*Astacus fluviatilis*).

The appearance presented by transverse sections of the muscles of the crayfish prepared by any of the ordinary methods is well known from the drawings and descriptions of van Gehuchten and other authors. The sections usually present large areas, divided into polygons of very various sizes and shapes, in different preparations, or even in different parts of the same section, though sometimes there is a certain degree of uniformity in the size of the polygons. I could not at first isolate longitudinal elements from the living muscles; and though longitudinal elements may easily be teased out from muscles fixed with alcohol or chromic acid, it seemed impossible to discover any constancy in their shape and size, and in the proportions

between their parts. It therefore seemed as though these muscles consist of great masses of indescribable substance, which, after the action of reagents upon it, splits into longitudinal elements, not corresponding in any way with functional elements of the living fibre. But it was possible to make out indications of varieties of cross-striation corresponding to all those characteristic of the various stages of contraction of the types of muscle described above, and I therefore felt certain that these muscles also consist of longitudinal elements comparable to the sarcostyles of those muscles. I was confirmed in this opinion by finding that it is easy to tease out from muscle, taken from the body about twelve hours after the death of the animal, fibrils which, in any one preparation, are usually of uniform size, although some seem to be destroyed in the process of teasing. These fibrils are very delicate and obscure objects when examined unstained in water or salt solution, and they cannot be certainly fixed by steam and stained with logwood, as can those of the wing muscles of insects. Nevertheless, they seemed to be cylindrical, and to present many points of similarity to these latter fibrils.

Transverse sections cut from the muscle frozen, while living, or after being steamed, in a drop of white of egg, do not confirm the pre-existence of cylindrical fibrils, and for some time I despaired of being able to bring these muscles into line with the types described above. But it was noticeable that, on cutting into a mass of the muscle, a watery fluid escapes in some quantity, and afterwards the muscle has a diminished bulk. It seemed, therefore, possible that the muscle consists of fibrils surrounded by a watery sarcoplasm, which contains too small a percentage of albuminous substances to be coagulable by heat or chemical agents, so that, as soon as the muscles are handled in any way, the fibrils fall together, and deform one another by mutual pressure. I therefore attempted to replace a watery non-coagulable sarcoplasm by an artificial coagulable sarcoplasm. Small pieces of muscle were carefully excised and transferred by aseptic methods to white of egg, in which they were allowed to soak for six days, the vessel containing them being kept in an ice-chest. At the end of this time the vessel was plunged into water at a temperature just below boiling-point, until its

contents were coagulated into a solid mass. The pieces of muscle were then excised from the mass of the coagulum, and transverse sections made with the freezing microtome from the parts next to the cut surfaces. Sections prepared by this method (see photo. 57) present a very different picture to that of sections made without the soaking in white of egg. They present large rounded areas about $100\ \mu$ to $200\ \mu$ across, which are the sections of approximately cylindrical muscle fibres. Filling up the angular spaces between the sections of the fibres is the finely dotted coagulum of egg albumen. The sections of the fibres are made up of small circular areas, which vary in diameter from $2\text{--}6\ \mu$ in different preparations, though fairly uniform in any one fibre (photos. 57 and 58). They are so closely set as almost or quite to touch one another, and in some parts they may be slightly flattened against one another. If such sections be stained on the slide with logwod, each of these small circular areas can be seen to be bounded by a fine darkly-stained line, and this seems to be the expression of a stained wall of the fibril, of which the circular area is the transverse section. The substance of the fibril within the line of the wall appears lightly stained, unlike the corresponding substance of the insect's wing fibrils. It appears, then, that by this method a watery sarcoplasm is replaced by the white of egg, which also replaces a thin body-fluid between the fibres, and this white of egg being coagulated by the heat, maintains both the fibres and their fibrils in their normal space relations, so that deformation by mutual pressure is prevented. This, at least, is the interpretation that seems most probable, and we shall see that it is supported by other observations.

There is another method of preparing transverse sections, showing a somewhat similar appearance, which, though less satisfactory than the method just described, is instructive. If the two distal segments of one of the 9th pair of appendages constituting the large claw be cut off, and the shell containing the muscles which move the terminal segment be carefully opened with scissors along either border, and then the two pieces of the shell remaining hinged at the base of the terminal segment be wedged open, like the valves of a mussel-shell, the muscle fibres within are stretched, and may be kept in a fully

extended state by putting a slip of cork of suitable thickness between the edges of the valves. If the muscle fibres be then fixed by immersion for some hours in chromic acid or formaline, while thus strung tensely between their natural attachments, and transverse sections be cut with the freezing microtome, the sections so obtained are made up of small polygonal areas, which, in the section of any one fibre, are uniform in size. If these sections be then kept on the slide soaking in 25 per cent. formic acid, they begin to swell, and the small polygonal areas lose their sharp angles, and become more and more rounded, until, in the most successful cases, they appear after some days as circular areas, corresponding in size to those of the sections prepared by the previous method. It is best to cut these sections rather thick. The circular shape is most readily produced in parts of torn sections of fibres at the periphery of the mass.

If slips from the muscles of the claw, fixed in the extended state by the method described above, be finely teased, there are found numerous isolated segmented fibrils. The fibrils so obtained are not uniform in width, but are polygonal in cross-section. Many of the fibrils show very distinctly an appearance of longitudinal wrinkling on the surface. If fibrils teased out in this way be kept soaking on the slide in 25 per cent. formic acid they swell slowly, until, after one or more days, they become cylindrical. In my most successful preparations by this method, every one of great numbers of isolated fibrils present a complete uniformity in size, shape, and general appearance. In preparations of the flexor muscles of the abdomen prepared by a slight modification of this method the size of the fibrils is usually uniform, but in preparations of the claw muscles at least two well-marked classes of fibrils can be distinguished by their difference in size, and I shall call these the large and small fibrils respectively. They are about $3.7\ \mu$ and $2.4\ \mu$ in diameter. When unstained, these fibrils are very obscure objects, since their refractive power is low. Nevertheless, it can be made out that they are crossed at regular intervals by dark lines, each of which has on either side of it a faint halo of light (photo. 50). These lines occur on the large fibrils at intervals of $7\ \mu$, and on the small at intervals of $4.5\ \mu$. In some fibrils a faint trans-

verse line can be seen midway between each pair of the well-marked lines, and about it, too, there is a faint suggestion of a halo. As I shall show, these seem to be the expression of transverse discs, comparable in every way to the α and β discs of the insect's wing fibrils. Fibrils prepared in this way can be stained with logwood, though the staining is very slow, and some hours of soaking in Ehrlich's hæmatoxylin are required to produce a deep staining. The staining brings out very strongly the close resemblance between these fibrils and those of the insect's wing muscles. The α discs always appear darkly stained, and the walls of the fibrils faintly stained (photo. 49), so that the longitudinal wrinkles of the wall are generally brought out more plainly.

The longitudinal wrinkles in the large fibrils, shrunken by the action of chromic acid, are very marked all through the length of the fibrils. But those which have been restored to their normal diameter by the action of formic acid show a separate set of wrinkles in the wall of each segment, which, just like those in the sarcomeres of the insect's wing muscle, are most marked at the middle, and fade away towards the ends of the segment. They are sometimes visible, though less marked in the B and C stages. It is just possible to make them out in fibrils teased out from the muscles twelve hours after the death of the animal. In many fibrils there are also stained in each segment three equidistant transverse lines, which correspond exactly in position with the lines γ β γ of the insect's wing fibrils, and are probably, like them, the expression of three transverse discs at these levels, since they are not merely surface markings, but are visible at all foci in the thickness of the fibril (photos. 51 and 53). The only difference between the appearance of these fibrils and those of the insect's wing muscle is, that the lines γ and γ usually appear in the former equally well marked with the β lines, whereas in the latter they are usually less well marked (cp. photo. 53 and photo. 11).

On comparing the photographs of the two kinds of fibrils, and the dimensions of their segments in this fully extended cylindrical state, as given above, we see that in both large and small fibrils of the crayfish muscle the relation of the length of the segments to their diameter is exactly the same as in the

fibrils of the insect's wing muscle. Then, if the α disc is inextensible, and the γ and β discs are extensible and elastic, but β less easily extensible than γ and γ , the segments of these fibrils present mechanical conditions exactly similar to those which I have tried to prove to exist in the sarcomeres of the insect's wing muscle.

Photo. 52 shows the appearance of muscle made up of large fibres 'en masse' in the stage A. Longitudinal dislocation of the fibrils is very common in all stages, and this and the following photographs of the muscle 'en masse' were purposely taken from parts showing considerable dislocations, for in them individual fibrils can be distinguished most readily. The teased preparation from which this photograph was taken was made by fixing a mass of fresh muscle from the claw with gold chloride, and reducing the gold by soaking in 25 per cent. formic acid in the usual way: in many cases the soaking in acid restores the fibrils to their normal shape, and from masses stained in this way fibrils may be isolated, showing the outlines characteristic of all the stages of contraction. In such preparations there is only a very little red-stained substance which seems to be a scanty coagulum from the watery sarcoplasm, and is deposited chiefly between the constricted parts of the fibrils. The fibrils seem to be very slightly contracted, so that there are indications of three darkly-stained bands on some of the segments, and these are probably caused by deposits of sarcoplasm at slight constrictions, due to the discs γ , γ , and β .

This exact correspondence in detail of the two kinds of fibril in the fully extended state, stage A, is exhibited also in the various stages of contraction of the fibrils. There may frequently be found, among the fully extended fibrils, fibrils in an early stage of contraction, corresponding to the β stage of the muscles already described (photo. 53). The segments of a fibril in this stage of contraction are shorter and a little broader than those in stage A (in the small fibrils they are about 3.5μ long by 3μ across, cp. photo. 53). The wall is constricted at the level of each of the discs α , γ , β , γ , and forms a rounded curve, convex outwards, between the ends of each pair of the discs. The outline of the wall can just be made out in the photograph. The halos of the α discs now just fill the interval between the α

and γ discs, so that the general appearance with a lower magnification is that of alternating dark and light bands of equal breadth, the latter being crossed in the middle by a dark line. Photo. 54 shows the appearance of the large fibrils in this stage 'en masse'; in it the α discs are scarcely distinguishable from the other discs. In places, the outline of the four bulging segments of the wall of each sarcomere can be seen. In parts in which there is no dislocation, the cross-striation caused by the α discs and their halos and the three intermediate discs is of course more sharply marked than it is in the photograph, but as there is scarcely any sarcoplasmic substance between the fibrils, and they, being cylinders, are seen in different optical sections in any one focus, there are therefore not to be found any well-marked longitudinal lines of sarcoplasm occurring at regular intervals, and showing the state of aggregation characteristic of this stage of contraction, such as there are in muscle fibres with lamellar sarcostyles.

Fibrils still more contracted in a stage corresponding to stage C of the other types of muscle also closely resemble the insect's wing fibrils in this stage (photo. 56). They may be prepared by the method described above, the stretching of the muscle being omitted; and, though with more difficulty than in the case of the extended fibrils, preparations may be obtained in which they are quite uniform in appearance. The segments exactly correspond in appearance and proportions to the sarcomeres of the insect's wing muscle in stage C. The fibril is constricted at the levels of α and β , while the γ discs can usually not be seen, though indications of them are sometimes to be made out: they are probably obscured by the halos of the α discs. The appearance of large fibrils 'en masse' in this stage is shown in photo. 55, in which the outline of the walls of the segments can be very clearly seen. Since the fibrils are seen in optical sections at different levels in the transverse vertical diameters, they do not appear uniform in width.

Though I have not photographed isolated fibrils in a stage of contraction corresponding to the D stage of other muscles, yet the character of the cross-striation in well-contracted parts of the living or fixed muscle indicates that this stage of contraction occurs, and I have obtained isolated fibrils in this stage,

their appearance being very similar to that of the insect's wing fibrils in stage D.

Also, as I have pointed out above, when fibrils are teased out from dying muscle of the crayfish, many seem to be disrupted and distorted in the teasing process, yet many remain showing the appearances and proportions of the parts characteristic of all the various stages.

There can, then, be little doubt that these fibrils of the skeletal muscles of the crayfish correspond accurately in every way to the sarcostyles of the insect's wing muscle, and they also may be called 'sarcostyles' and their segments 'sarcomeres.'

Transverse sections prepared by the methods described above show that, allowance being made for differences in the levels at which the sarcomeres are cut, the fibrils of any one fibre are of one size, but in different fibres there occur differences in the size of the sections of the fibrils, corresponding to the large and small fibrils already described. But besides these two classes, there is at least one other well-marked class of very small fibrils occurring in the body muscles, of which the diameter is only about 1.5μ and the length of the segments 3μ , but which, as far as I can make out, resemble the larger fibrils in every particular. The largest fibrils that I have found occur in the muscles of the great claw. This distribution of the large and small fibrils is interesting when looked at in connection with the fact that the body muscles execute very sudden and rapid movements, while the movements of the claw seem to be always slow.

It is perhaps worth while to point out that the swelling in formic acid of shrunken and deformed fibrils until they regain their normal shape and size further strengthens the view that the fibrils are membranous tubules, for it is difficult to suppose that fibrils of any other nature would behave in this way. This swelling under the action of formic acid is best illustrated by teased preparations made by Rollett's method of negative gold staining. This consists in fixing the fresh muscle in strong alcohol, and soaking it in glycerine before the immersion of it in the gold chloride and acid. After this treatment there may occasionally be teased out, from all the types of muscle that I have described, isolated sarcostyles showing the outlines proper to the living state. Lamellar sarcostyles prepared by this

method often show the constrictions characteristic of the various stages of contraction much better than those obtained from chromic acid preparations. But the method is very uncertain in its results, for often the parts are too much swollen, and the septa β and γ no longer exert their constricting action.

The Leg Muscles of the House-Fly.

The leg muscles of the common house-fly are of two slightly different types. Those of the one type seem to be exactly similar to the leg muscles of the water-beetle. Those of the other type differ from these in that the muscle columns, instead of being arranged in a simple radiating system around the central core, are very narrow, only about $5\ \mu$ in their radial width, and are arranged in concentric circles or tiers, the columns being radially arranged in each tier. So that, in transverse section (photo. 59), the broad rings marked by the narrow radial areas, the sections of the muscle columns, and by the lines of sarcoplasm between them, alternate with concentric narrow rings of granular sarcoplasmic substance. There may be two, three, four, or even more of these concentric rings. They are not literally circular in shape, but are long ovals, corresponding to the shape of the central core of sarcoplasm. The appearances to be seen on the longitudinal aspect of the fibres are practically identical with those of the leg muscles of *Dytiscus*. The fibres occur frequently in the fully extended state without having been artificially stretched out. Rollett has figured them in that condition, and has perhaps derived from them his belief that the living muscle columns of muscle in general have an equal thickness in their whole length. The proportions of the length of the segments, as marked by the α septa in this stage A, to their thickness, is the same as in those of the lamellar sarcostyles of the beetle's leg muscle and of the frog's muscle, for they are about $5\ \mu$ long by $1.5\ \mu$ in thickness. Their radial width is less than that of these other columns; but this, as we have seen, does not affect the mechanical conditions appreciably so long as the width is considerably greater than the thickness.

In all the stages of contraction, as determined by the lengths of the sarcomeres, the appearances correspond exactly with those

of other lamellar sarcostyles, each sarcomere going through a similar series of changes in shape, and I have not thought it worth while to give a series of photographs representing these stages.

The narrow lamellar sarcostyles can be readily isolated by teasing, after fixation with chromic acid. They can also be isolated after fixation with the mixture of chromic and formic acids, and then show no longitudinal wrinklins of the walls.

These muscle fibres must then be considered as different from those of the water-beetle's leg muscles simply in the peculiar arrangement of the sarcostyles in two or more concentric rings.

Other Types of Cross-striated Muscle.

I have examined several other types of cross-striated muscle, and have found none that will not fit into the scheme of structure common to the types described above. I have found indications that the lamellar sarcostyle may have been evolved by the apposition of several cylindrical ones, and that some retain indications of such a composite origin, though now being functionally single organs. But these observations, when more extended, I hope to embody in a second paper on cross-striated muscle.

Is there more than one kind of substance occupying the chambers of the Sarcomeres?

It is one of the oldest and most generally received dogmas as to the striated substance of muscle fibres that in the uncontracted state of the fibre it presents an alternation of dim and light bands, and that these are due to alternating layers of substances which transmit the light differently. It is generally stated that the 'dim substance' stains darkly with all the ordinary stains, especially logwood, and is anisotropic; while the 'bright substance' does not stain so readily, and is isotropic. Further, it is said that during contraction the dim bands become bright and the bright bands dim. Some authors have even gone so far as to speak of the 'dim substance' as the 'contractile' part of a muscle fibre.

In the fully extended state, stage A, and in stage B, both the isolated sarcostyles and the muscle fibres as a whole present the appearance of alternating dim and light bands, and the dim band is usually brought out more strongly by staining with logwood (see photos. 2, 21, 24, 51, 53). I have already pointed out that it is not necessary to assume the existence of two different substances in the sarcomeres to account for this appearance. The bright band is in all cases chiefly due to the refraction halos bordering the α septa. In the case of the isolated cylindrical sarcostyles, the folding of the wall being most marked at the middle of each sarcomere, increases the dimness of this part, especially when the substance of the wall is stained.

There is sometimes produced in this way a very well-marked appearance of a stained band, and with an inferior lens it would be quite impossible to make out that the staining resides in the wall only. But with the 2 mm. apochromatic objective it is easy to make out that the staining is always at the surface only, for it is darkest at the borders and palest at the middle of the width of the sarcomere (photo. 2). That the high refractive power of the α disc is the cause of the bright band is proved by the observation of living or stained fibrils in the various stages of contraction. In stage B, the bright borders of the α disc generally just fill the interval between it and the γ discs on either side (photos. 3 and 53), and then if the γ discs be stained the 'dim band' appears very sharply marked off from the bright band. In stage C the bright borders of the α discs, supplemented perhaps by the narrower borders of the β discs, light up the whole length of the sarcomere, and since the foldings of the wall are much less deep in this stage, there is no appearance of a dim band even when the fibril is darkly stained with logwood (photos. 5 and 6). In the case of the whole fibres, with a relatively small amount of sarcoplasm, the cross-striation is largely determined in all stages of contraction, except stage A, by the distribution of the sarcoplasm.

That there is no staining of the contents of the sarcomeres in the chambers between their transverse septa is proved by the study of transverse sections of muscle fibres with cylindrical sarcostyles, and of longitudinal and transverse sections of fibres with lamellar sarcostyles. I have made a very large number of

such preparations of insects' wing muscles and the water-beetles' leg muscles, using the freezing method, in order to avoid the shrinkage which seems inevitably to result from embedding in paraffin. The muscles were fixed with steam, chromic acid, the chromic and formic mixture, Flemming's fluid or formaline, and stained as deeply as possible with hæmatoxylin, either 'en masse' or when on the slide. (For this purpose, I have used both Ehrlich's and Delafield's preparations of logwood. The stain is taken especially rapidly and well after fixation with formaline.) The sarcoplasm and the walls and septa of the sarcostyles alone appear stained (cp. photos. 17, 18, 36, and 58). The only kind of sarcostyle of which this is not certainly true is that of the crayfish, in which, I believe, the contents may sometimes be lightly stained, but much less darkly than the walls and septa. I have found exactly similar results on staining with methylene-blue and methyl-violet.

There is, then, no reason to assume the existence of the 'dim' and 'bright' substances to explain the appearances of the living muscles, nor does staining with hæmatoxylin, after fixation with the agents mentioned, afford evidence of the existence of such substances.¹ It has usually been said that the dim substance is anisotropic, and the bright substance isotropic. But Schäfer, in his paper on "The minute structure of the leg muscles of the water-beetle," calling the lines of sarcoplasm in the fully extended state of the muscle, muscle rods, states that the substance between them (*i.e.*, the muscle columns) is anisotropic in all its length, and points out that this conclusion is in agreement with observations recorded by Heppner and Merkel.

I have therefore thought it unnecessary to examine muscle fibres with the aid of Nicol's prisms, since it seems clear from these statements that the method does not afford evidence of any differentiation of substances in the muscle columns.

There remains, then, so far as I know, only one piece of evidence that is supposed to show the existence of the two substances in the sarcomeres. It consists in the effects produced by the method of negative gold staining as recommended by Rollett. The process consists in soaking the fresh muscle first in 93 p.c. alcohol for twenty-four

¹ I leave until a later part of this section the description of the staining effects of logwood on muscles fixed with alcohol.

hours or more, then in glycerine for some hours, then in 1 p.c. gold chloride for half an hour or less, and in 25 p.c. formic acid in the dark until the gold salt is reduced.

Rollett (2) states that by this process, while some parts of the fibres are generally stained in the same way as when the fresh tissue is brought into the gold chloride, in other parts the staining is the reverse or negative of this, the muscle columns being stained and the sarcoplasm left unstained.

Schäfer (1) has recently described certain appearances in the wing muscles of insects produced by this method of staining. He states that in extended sarcostyles there is a longitudinally striated band of stained substance occupying the middle part of each sarcomere, and separated from the disc at either end by a narrow band of unstained substance; that contracted sarcomeres are bulged out at their middle parts, and the stained substance comes almost into contact with the discs, so that the unstained interval almost disappears; that the striæ on the stained band can be followed across the clear interval to the disc; that the stained part of the sarcomeres, which he calls the sarcous substance or disc, is sometimes separated in teasing, and that, if an end view of it be obtained, there may be seen tiny unstained circular areas, bounded by stained substance. This last appearance Schäfer interprets as the expression of a system of longitudinal tubules in the sarcous substance, and attributes to them the appearance of longitudinal striation presented by the substance, and he supposes that during contraction the fluid substance of the clear interval passes into the tubules of the sarcous substance.

Since the existence of any such an arrangement in the sarcomeres seems to me not easily reconcilable with the existence of the transverse discs γ , γ , and β , that I have described, and since my observations on preparations made by this method have led me to a conclusion different to that of Professor Schäfer, I have made a very large number of preparations by this method, using the wing muscles of various insects, and the leg muscles of the water-beetle. Since the effects of the staining process are very variable, the details of the process were varied slightly in different ways with each preparation. Of these preparations, very many were rejected as failures, but in about one hundred of them there were large parts, sometimes nearly the whole, in which the muscle columns were stained. These preparations were examined in glycerine, after being teased or cut with the freezing microtome into transverse and longitudinal sections as thin as possible.

As the differentiation into stained and unstained substance is said to be best seen in extended sarcomeres, the wing muscles of

the water-beetle were generally pinned out in a fully extended state during their fixation by the alcohol. The fibrils of the wasp's and still more of the house-fly's wing muscles are very frequently found in the extended state, so that it was not necessary to pin them out. In the case of the beetle's wing muscles, both in contracted and extended fibres, the most frequent result of the staining is, that the fibrils are darkly stained throughout their whole length. This can be clearly seen throughout large areas of thin longitudinal sections. This occurs both when the fibrils are much swollen and when they are of normal width, or remaining shrunken to less than their normal width. But it is also common to see narrow unstained lines at the levels of the α discs; and when the staining is rather light, the refraction halos of the discs generally assert themselves, making the middle of the sarcomeres appear the darkest parts. The corresponding appearance in the isolated sarcostyle is shown in No. 1 of Schäfer's published photographs.¹ In similarly prepared longitudinal sections of fibres from the wasp or house-fly, the fibrils sometimes appear stained throughout their length, but more commonly the α discs are visible as bright unstained lines. When the α discs are $4\ \mu$ apart, it is possible to be quite certain that such fibrils are fully extended if their width does not exceed $2.2\ \mu$, the length of the diameter of the living sarcomere in stage A. For though the sarcomeres often become very much swollen under the action of formic acid, increase in width is generally alone present, and increase in length never occurs without considerable increase in width.

In the best preparations of this kind, especially of fibres from the house-fly, the γ and β discs can also be seen as bright unstained lines, which can be focussed through the thickness of the sarcomeres. This method, then, gives valuable confirmation of the presence of the γ and β discs in these sarcomeres. The discs vary in the degree to which they assert themselves, just as they do in the living fibrils, and in fibrils stained with logwood. In some cases the β disc appears nearly as well marked as the α disc, in others it seems as delicate as the γ discs.

In thick longitudinal sections, there is in parts in which the

¹ These photographs are published, with a preliminary account, in the *Proc. Roy. Soc.*, vol. 49.

α discs remain clear a well-marked cross-striation, for the light is almost quite stopped by the stained bodies of several superposed sarcomeres, while it comes freely through the narrow planes of superposed α discs. If the β disc is well marked, the striation is, as it were, doubled. Where the fibrils are contracted and the α discs unstained, the general appearance of cross-striation is even better marked, for the clear gaps caused by the α discs are just as well marked as before, and the widest part of each stained segment is in the middle of its length, and this part, therefore, colours the light most deeply.

To understand the difference between these two kinds of staining of the fibrils resulting from this alcohol gold process, namely, the staining of the whole length of the fibril and the staining of the substance in the four chambers of the sarcomeres only, it is necessary to consider a third kind of staining which not infrequently results. This third kind is a staining of the discs α and γ and β and of the side walls, just like the staining of logwood; the substance in the chambers of the sarcomeres remaining unstained. It seems probable that the kind of staining first described, namely, that of the whole length of the fibrils, is, as it were, a combination of the two other kinds, *i.e.*, that the discs and walls are stained as well as the contents of the chambers. When sarcostyles are stained only very lightly in this way, the discs are usually more darkly stained than the contents of the chambers, and therefore appear as dark lines across the lightly stained sarcomeres at α , γ , γ , and β . In all these cases I have only seen the γ discs distinctly in sarcomeres not contracted more than to stage B.

It is characteristic of fibrils stained in the third way that they are very coherent, and may be very easily teased out in large numbers, and in the whole of their length, while, when it is attempted to tease fibres stained in the second way, *i.e.*, the contents only of the chambers being stained, they break across very readily, so that it is difficult to tease out any but short lengths of fibrils. In this breaking across, the fibrils are ruptured about the level of the α discs.

It is also characteristic of fibrils stained in the second way that, during teasing, fibrils sometimes become drawn out in such a way that the intervals between the discs are much in-

creased. Larger or smaller clear gaps then occur between the stained contents of the successive sarcomeres (see Schäfer's photo. 2 a. 13). Sometimes the stained mass of each sarcomere is drawn into two distinct parts, the separation occurring at the β disc, and sometimes it is drawn into four distinct parts, with clear gaps between. This last appearance I have not myself seen, but it has been recorded by trustworthy observers. There can, I think, be little doubt that in this last case the separations are at the γ , γ , and β discs, and that the four stained masses represent the coagulated and stained contents of the four chambers of the sarcomere.

This drawing out of the wall of the sarcomeres is a process not easy to understand. It seems to imply a well-marked ductility. (A similar effect may be very commonly seen when fibrils are teased out from the muscles of a crayfish some hours after the death of the animal.) The coagulated contents of the chambers of the sarcomere are probably slightly shrunken away from the wall, so that they are not intimately connected with it, and may be drawn with it in different degrees or not at all, or tilted a little within the walls, according to the degree of the connection. Slight shrinkage of the coagulated contents may, perhaps, account for the fact that the gap in the stained substance at the disc α occasionally appears even in longitudinal sections of fibrils 'en masse,' slightly wider than the thickness of the α disc. This occasional appearance may, I think, be explained in this way with much greater probability than by assuming that in them there is between the α discs and the stained substance a very narrow band of substance remaining unstained, although in the great majority of preparations it stains exactly like the rest of the substance. That this slight gap is not due to a narrow band of the substance within the sarcomere remaining unstained is proved by those cases of this kind in which the stained substance of the sarcomere can be clearly seen to be made up of four equal pieces, separated from one another by the γ , γ , and β discs. It is possible that the slightly increased breadth of the gap between the contents of neighbouring sarcomeres in these exceptional cases is due to the α disc itself being increased in thickness by the action of the acid. Sometimes, though still more rarely, the width of the gap

in the stained substance due to the unstained β disc also appears rather greater than the normal thickness of the disc, and this is probably due to the same causes. It is often possible to see in muscles treated with alcohol and acid, and especially in the fibres of the beetle's leg muscles, that the α disc is much swollen in thickness.

I have, then, failed to find in my numerous preparations of these fibrils by this method any evidence of the presence of two substances in the sarcomeres, such as Schäfer has stated to be present. Is this result to be regarded merely as a failure of the method in my hands? I think not, for a critical inspection of the photographs published by Schäfer shows that they will not bear the interpretation put upon them by him (13).

The enlarged photographs represent the fibrils magnified 2300 diameters. On carefully measuring these with a pair of dividers and a millimetre scale, and dividing the lengths in millimetres so obtained by 2.3, we find the lengths in μ of the parts of the objects photographed. The living sarcomeres of the wasp are very constantly of the same dimensions: in stage A they are 4μ by 2.2μ , and when contracted to about 50 per cent. of their length they are about 2μ long and nearly 4μ in diameter. I have already stated that, although increase in the length of the sarcomere is found sometimes in sarcostyles which have been very much swollen by the action of the formic acid, yet it never occurs without there being considerable increase in width of the same sarcomeres. If, then, a sarcomere, after being stained by the negative gold method, is of the same or less diameter than living sarcomeres of the same length, we can be sure that there has been no swelling in the longitudinal axis, and the measurement of its length enables us to determine with certainty its stage of contraction.

In the plates accompanying Schäfer's description of the wing sarcostyles in the *Proc. Roy. Soc.*, vol. 49, the first of the two photographs (numbered 1.a) is said by Schäfer to represent part of a retracted sarcostyle. Its segments are about 1.7μ long and 3.7μ wide. We may therefore conclude that they have almost their normal dimensions, and are contracted to a late C stage. It will be noticed that no trace of an unstained segment is present.

The segments of the sarcostyle in the photograph numbered (3.a) are 3 μ long and almost 4 μ across. They might therefore be interpreted as being in stage B of contraction, and rather swollen in width (a living sarcomere in stage B is 3 μ long and 3 μ across). But there are objections to this interpretation. Firstly, the clear intervals between the dark bands are very unequal in breadth, some being twice as broad as others. Secondly, the two uppermost black bands in the photograph are in contact with one another, so that there is no clear interval between them. Thirdly, the lower one of these two upper bands is in contact with the next lower band at one edge of the fibril, and separated from it at the other edge, showing that these two bands, at least, are not in their normal position, but have suffered dislocation of some kind during teasing. Since the two upper black bands are of the same width as the others, it cannot be supposed that they are in a more contracted state. The black bands are nearly 2 μ long and nearly 4 μ broad, *i.e.*, almost exactly of the same dimensions as the sarcomeres of the fibril in photo. (1.a) already examined. It is therefore necessary to conclude that each black band represents the whole length of a sarcomere in a well-contracted state, and that the photograph represents part of a sarcostyle in the same stage of contraction as that in photo. (1.a), though very slightly more swollen, but that during teasing some of the segments have been drawn apart from one another to unequal degrees, and that the appearance of clear intervals between the stained segments has been produced in this way. There seems to be some confusion in the numbering of the photos. 2 and 3, and the references to them in the text of Schäfer's paper, so that I cannot be certain whether he regards this fibril of photo. 3 as typical of the retracted or extended condition. But it seems probable that he regards it as extended, for his sole means of judging of the state of contraction or extension seems to be afforded by the absence or presence of the clear intervals between the stained segments.

In photo. (2.a) the length of the sarcomeres is about 7 μ and their width 2 μ . They are therefore very much over-extended. The stained segment is made up of two parts, slightly separated from one another: each is 2 μ long and 2 μ broad. Together they make up 4 μ , the length of a fully extended living sarcostyle.

I would therefore interpret each of these black bands as the contents of the one-half of a sarcomere, *i.e.*, the substance between the α and β discs, the living fibril having been fixed by the alcohol in the fully extended state, and the further extension having been produced during teasing. This photograph is described as representing part of a retracted sarcostyle, but in this case also it is impossible to make sure of what is Schäfer's opinion respecting it, owing to the confusion mentioned above.

In photo. (4.a) the sarcomeres of the upper part are $5.7\ \mu$ long and $2\ \mu$ broad. The black segments are $4\ \mu$ long and $2\ \mu$ broad. Since the fibril shows unmistakable evidence, in the obliquity of some of the bands, of artificial stretching during its preparation, it is fair to interpret the black segments, $4\ \mu$ long, as the stained contents of sarcomeres fixed in the fully extended state, and afterwards stretched during teasing, the clear intervals being so produced. The segments are slightly shrunken, since they are only $2\ \mu$ across, while in the living state they are $2.2\ \mu$ across. Turning to the lower part of the photograph, we find black segments $2.2\ \mu$ long and $3\ \mu$ wide, and separated by clear intervals, rather longer than those in the upper part of the photograph. These black segments seem to represent the stained contents of sarcomeres fixed in stage C by the alcohol, and afterwards drawn apart during teasing. They remain slightly shrunken in width, like those in the upper part of the photograph.

In photo. 5 the fibrils are said to be moderately extended. The black segments are separated from one another by clear intervals of very different lengths, and many of them are tilted in different ways. The black segments are $2.3\ \mu$ long and $3.8\ \mu$ broad, and these are the dimensions of a living sarcomere in an early C stage. Each black segment, therefore, probably represents the stained contents of a sarcomere fixed in that stage, and the clear intervals have been produced during teasing. The second of the two photographs numbered 1.a I do not know how to interpret, unless it be of one of the smaller-sized fibrils (such as that shown in my photo. 2) which occasionally occur. For in appearance and proportion of parts, it exactly resembles fibrils stained in their whole length in stage B. If it be a fibril of the usual size, it must be a good deal shrunken in width, and fairly well contracted, *i.e.*, to an early C stage.

I have found in teased preparations fibrils in all stages of contraction showing considerable clear intervals between the stained segments, just like those in Schäfer's photographs. But, like these, they generally show unmistakable signs of having been dragged during teasing, either in an abnormal length, an irregularity in the size of the clear intervals, or an obliquity of parts. There can usually be seen fibrils still 'en masse' lying near the separated fibrils, and like them in every respect, except that they have no clear intervals between their stained segments wider than the line which is the expression of the α disc. The simple fact that a part of a fibril appears isolated in a teased preparation is enough to prove that it has suffered some dragging,—enough, at least, to break it across and separate it from its fibre. Schäfer does not seem to have avoided this by making thin longitudinal sections.

This series of photographs, then, so far from proving the existence at either end of the sarcomere of a band of substance which remains unstained while the middle parts become stained, affords evidence that in the fibrils represented in the photographs such bands of substance do not exist. For when the state of contraction of the sarcomeres is determined in the only legitimate manner, namely, by measurement, it is found that in every case the stained substance corresponds in size to the size of the sarcomeres in the stage of contraction in which they were fixed, and therefore the stained substance must have occupied the whole length of the sarcomere.

Longitudinal sections of fully extended fibres from the leg muscles of the water-beetle, stained by this method, show that where the muscle columns are stained, they are stained in their whole length, and so strengthen the evidence afforded by the wing fibrils. An appearance of a well-marked dark band is often produced in these fibrils by this staining process, in the following way. The shrinkage produced by the alcohol most affects the middle parts of the sarcomeres, and the sarcoplasm becomes accumulated at these levels in the masses described by van Gehuchten as 'batonnements' on the longitudinal strands of his network. These become stained with gold, and so cause by optical fusion the appearance of a darkly-stained band. Other causes may also produce a general appearance of a darkly-

stained band; for example, the dark staining of the γ and β disc in each segment.

I am of opinion, therefore, that this method of negative gold staining does not afford evidence of the presence of substances of two kinds in the chambers of the sarcomere.

In describing the staining effects of logwood after fixation with various agents, I did not describe the effects produced after fixation with alcohol, and these effects must now be described. If a slip of the wing muscle of the wasp, house-fly, or water-beetle be put through the preliminary stages of the negative gold method of staining, *i.e.*, if it be soaked in strong alcohol and then in glycerine, and then be immersed in rather a dilute preparation of hæmatoxylin for one or more days, and afterwards cut with the freezing microtome into thin longitudinal and transverse sections, it is found that the staining effect of hæmatoxylin is modified by the previous treatment with alcohol, in just the same way as the staining effect of gold chloride. The sarcoplasm in most parts remains quite unstained. Sarcostyles are found stained in all the three ways in which they become stained by the negative gold method, namely, the substance of the sarcostyles is stained darkly in its whole length; or the discs α , γ , β , γ and the walls are stained, while the contents of the chambers of the sarcomeres remain unstained; or, thirdly, only the contents of the chambers are stained, the discs and walls being left unstained. The first kind of staining is the most common.

If fibres stained by this method be finely teased, sarcostyles presenting all the three kinds of staining are usually to be found in the preparation, but there are usually a few others which present darkly-stained bands alternating with narrow clear bands. Usually the stained band occupies the middle part of each segment, but often it consists of two parts, separated by a clear band of variable width. These clear bands are due to a pulling out of the walls of the sarcomeres during the process of teasing, just like those which may appear in teased preparations of sarcostyles stained by the negative gold method. The proof of this consists in the following facts. Firstly, in preparations made by cutting thin longitudinal sections with the freezing microtome there occur many isolated parts of sarcostyles, yet

these never present clear intervals between the stained segments wider than the clear line which is the expression of the unstained α disc in sarcostyles with the third kind of staining.¹ Secondly, the sarcostyles which present clear bands between the segments usually present unmistakable signs of having been dragged, in an inequality of the widths of the clear bands, in obliquity of the discs or stained segments, or in an absence of the clear bands in some sarcomeres, which otherwise exactly resemble the rest. Thirdly, the clear band is often just as wide in contracted as in extended sarcostyles. Fourthly, there can usually be seen fibrils still 'en masse' in neighbouring parts of the field, exactly like those showing the clear bands, except in the absence of the clear bands. It is clear, therefore, that this staining with logwood after fixation with alcohol does not afford evidence of two kinds of substance in the chambers of the sarcomere, and confirms the conclusion drawn from the study of preparations by the negative gold method.

We have now examined, and found to be fallacious, the four kinds of evidence on which the belief in the existence of the 'dim' substance has been founded, and I know of no other evidence supporting the belief.

With regard to the tubular structure ascribed by Schäfer to the contents of the sarcomere, I have only obtained negative evidence, by the examination of many transverse sections of fibrils stained by the negative gold method. The contents of the sarcomeres usually contain a number of darkly-stained granules, about $\cdot 2$ to $\cdot 3 \mu$ in diameter. When one of these granules is looked at with a focus slightly too high, it appears as a tiny dark ring with a clear centre. This appearance of tiny rings is seen equally well in the longitudinal and transverse views of sarcomeres. But in the view of a transverse section all the granules at one focus may appear as rings, giving an appearance exactly like that of Schäfer's photo. 8.S'. This arrangement of the granules in transverse planes is due to their being contained in the chambers of the sarcomere, which, when

¹ Perhaps the cases in which the clear band is most unmistakably the result of a dragging of the fibrils are those fibrils in which a clear interval occurs between one or two pairs of segments only, these being correspondingly longer than the other segments, between which there are no clear bands. This I have seen, though rarely.

the sarcomere is contracted to any appreciable extent, are so shallow as to allow of only a single layer of granules between the discs by which they are bounded. This arrangement of the granules in a single layer between each pair of discs can sometimes be made out in the longitudinal aspect. Although Schäfer states that the appearance of tiny rings can be made out at all foci, he does not state that he has been able to follow any one ring, as such, through any part of the depth of the sarcomere, as it would be easy to do if the rings are the optical expression of tubules. Nevertheless, my failure to find tubules has of course only a negative value, and it must be supposed that Schäfer's preparations show an appearance of rings which cannot be easily seen to be due to stained granules.

The preservation of the regularity of the Cross-striation.

If the striated substance of a muscle fibre consists of longitudinal elements, the muscle columns, lying side by side in a liquid or viscid medium, and if they are not in any way tied together at intervals in the whole length of the fibre, how comes it that the corresponding parts of neighbouring columns are nearly always found forming continuous lines across the fibre with the most wonderful regularity?

When a living fibre from the leg muscles of *Dytiscus* is watched under a high power of the microscope, it can be seen that the regularity of the cross-striation is sometimes locally destroyed by the unequal contraction of neighbouring muscle columns. Each muscle column is then much more clearly marked out from its fellows, and its α septa can be clearly distinguished; the lines α of neighbouring columns sometimes form in such cases a series of steps across this part of the fibre. But any such irregularities are very soon rectified in a living fibre. The passage of a small nematode worm along the fibre, temporarily displacing the transverse striæ, as recorded by Kühne and v. Eberth, affords another illustration of this wonderful power of rectification of the cross-striation that is possessed by the living fibre. In dead fibres there are often found breaks or 'faults' in the cross-striation. I would offer the following suggestion towards the explanation of the phenomenon.

Confining our attention to a fibre of the leg muscle of *Dytiscus*, let us consider the relation of the sarcoplasm to the muscle columns. In the fully extended state the sarcoplasm occupies narrow planes between the columns, besides surrounding the nuclei at the central core of the fibre. When the columns are contracted to stage B, the sarcoplasm occupies small linear radial spaces at the constricted levels of the columns, which are shut off from one another by the coming in contact of the bulged parts of neighbouring columns.

Transverse sections of these spaces or chambers parallel to the long axis of the fibre are roughly diamond-shaped (see fig. 17). But if the corresponding parts of neighbouring muscle columns are not at exactly the same transverse level, the section of the chambers has the shape of the clear area in fig. 18. If now the columns contract further, they press equally against one another and against the sarcoplasm, and both columns and sarcoplasm have to expand laterally

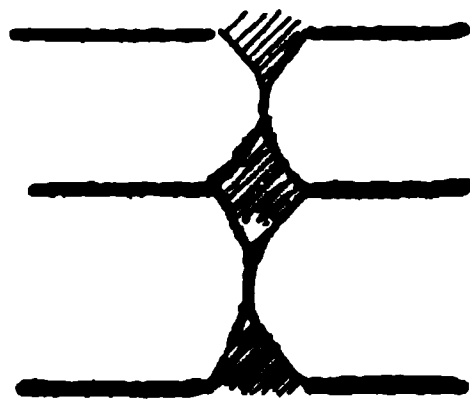


FIG. 17.

against the elastic resistance of the sarcolemma, and a greater quantity of sarcoplasm has to be packed away between the same lengths of the muscle columns. The sarcoplasm must therefore exert an increasing fluid pressure upon the walls of the spaces in which it is contained as contraction proceeds. Then, if at any part the cross-striation is not perfectly regular, *i.e.*, if any of the spaces between the muscle columns present in section a shape such as that shown in fig. 18, there is a

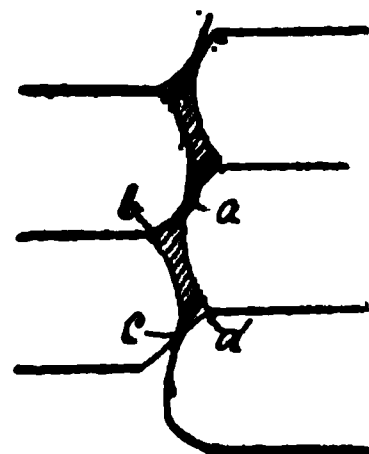


FIG. 18.

greater number of units of area on the walls *a.d* and *b.c* than on the walls *a.b* and *d.c*, and therefore there is a greater force tending to drive apart *a.d* and *b.c* than that which tends to drive apart *a.b* and *d.c*. Since the walls are not fixed relatively to one another, the result will be that, as contraction proceeds, the shape will tend to become diamond-shaped, *i.e.*, to have its sides reduced to equality, and *a* and *a* will be brought into the same straight line. In all stages of contraction in muscle fibres

with muscle columns of any other shape the conditions will be similar, though more complex.

I would here insist for the last time upon the significance of the fact that, while in all the different types of muscle fibre that I have described the absolute size of the sarcomeres is subject to very considerable variations, the relation of their length to their transverse measurements is always a very definite and constant one; and this relation is such that whatever the size and shape of the sarcomere, if only it contain fluid substance and be divided by three elastic septa, such as I have supposed, then whenever its ends are approximated by any force, it must exhibit the regular series of definite changes in shape that I have described. This constancy of the conditions of shape and volume in such widely different types of muscle cannot be a mere coincidence, and to me seems to be in itself very strong evidence of the truth of my account of the structure of the sarcomeres, for I cannot imagine what would necessitate the constancy of these conditions in the presence of any other structure, and still less in the total absence of structure.

*Summary of the Conclusions arrived at in respect to the
Structure of Cross-striated Muscle.*

I will conclude this paper with a brief statement of the most important propositions which may, I think, be regarded as rendered highly probable by the observations and arguments set down above.

1. The striated substance of the muscles of several arthropods and vertebrates of widely different groups, and therefore probably of most members of these families, is of fundamentally the same nature.

2. These muscles consist of longitudinal contractile elements, the sarcostyles, embedded in, and more or less separated from one another by, a protoplasmic substance, the sarcoplasm.

3. The sarcostyle consists of a longitudinal series of hollow chambers, the sarcomeres, joined end to end, and separated from one another by complete transverse septa. The walls of the chambers and these septa between the chambers are of a membranous nature, and practically inextensible. The cavity of

the sarcomere is divided into four equal chambers by three transverse septa of extensible elastic membrane, of which the middle one is less easily extensible than the other two. The chambers of the sarcomere contain fluid substance.

4. While the shape and absolute size of the sarcomere is different in different animals, and often in different muscles of one animal, the proportions and dispositions of the parts of the sarcomere are in all cases such that any shortening must be accompanied by a pressure of the fluid contents upon the walls of the sarcomeres, and that, under the influence of this pressure, the side walls must bulge outward, dragging out the extensible septa, which, by their elastic reaction, constrict the wall, and cause the whole sarcomere to go through a perfectly definite and regular series of changes in shape as the shortening goes on. These changes in shape are very slightly variable in any one type of sarcomere, but are essentially similar in all the different kinds of muscle described above.

5. The above account of the structure of cross-striated muscle affords a basis for legitimate speculation as to the nature of the processes which immediately determine contraction, and the formation of hypotheses, the truth of which we may reasonably hope to affirm or deny at some future time.

6. The results obtained in these investigations justify the working hypothesis adopted at the outset, rendering its truth highly probable, and they emphasise the importance of the method used. The hypothesis adopted was that living cross-striated muscles consist of substances which, so far as their mechanical properties are concerned, may be defined and classed in the same way as non-living matter, namely, as solid, viscous, and fluid substances; and the method used was to attempt to explain all the phenomena in terms of this hypothesis, and when this seemed at first impossible, to attribute this to the complexity and obscurity of the conditions of observation, rather than to suppose such a fundamental difference in the nature of the living substances as would make it improper to attempt to regard them as being among those phenomena which have a mechanical aspect.

A Suggestion as to the nature of the Physical Processes that determine 'Contraction.'

The investigation of the structure of muscle, the results of which have been given in this paper, was undertaken in the hope of finding such evidence of mechanical structure as would afford a basis for a hypothesis that I had conceived as to the nature of the contractile processes. My account of the structure cannot fail to suggest the hypothesis in question to every ingenious person. I will therefore set it down very briefly here.

If by any means the volume of the fluid contents of the chambers of a sarcomere is increased, the side walls must be bulged outwards, drawing together the end walls of the sarcomere, the septa *a*. For this is the only way in which its cubic capacity can be increased. In describing the stages of contraction of the sarcomere, I have assumed that it goes through all the changes in shape without any change in volume, as would be the case if its end walls were pushed towards one another by external forces; but if the elastic septa were stretched ever so little more at each stage, there would be a continuous increase in the cubic capacity of the whole sarcomere, with so slight a difference in its outline at each stage as would be unrecognisable under the microscope. My suggestion is that the immediate cause of contraction is an increase in the volume of the fluid contents of the sarcomere, and I would formulate my hypothesis as follows:—*Contraction is the result of an increase in the volume of the fluid contents of the sarcomere, and relaxation is accompanied by a diminution in their volume.*

That an increase in the volume of the fluid contents of the sarcomeres is an efficient cause of shortening of at least 40 p.c. of their length, is proved by the observations previously recorded. I have described how, under the action of 25 p.c. formic acid, a sarcostyle, fixed or partially fixed by strong alcohol, may be seen to shorten by at least 40 p.c. of its length, with the changes in appearance characteristic of normal contraction; and that this is due to an increase in the volume of the fluid contents of the chambers of the sarcomere is shown by the fact that, after a more prolonged action of the acid, the elastic septa may cease to exert their constricting action, each sarcomere then swelling up as a single chamber to its barrel-shaped form of maximum

cubic capacity, elongating, in doing so, if there has been a well-marked shortening. I described also what seems to be an analogous effect of very weak acid on living sarcostyles.

Are there, then, any indications as to the means by which such an increase in volume of the contents of the sarcomeres may be effected? Two possibilities present themselves: such an increase of volume may be carried by (*a*) the production within the sarcomeres of new substances that occupy a larger space than their parent molecules; (*b*) the passage of fluid into the sarcomeres from the sarcoplasm. It is now very generally believed that the chemical changes that determine contraction consist in a breaking up of a large molecule or molecules, the so-called 'inogen,' into a number of smaller, more stable molecules. Since, as we have seen, the sarcomeres are the contractile elements, and may be seen to contract when lying in an inert fluid such as white of egg, it seems highly probable that this breaking up of large molecules into more numerous smaller molecules takes place in the fluid substance occupying the chambers of the sarcomeres. Such an increase in the number of molecules in solution in the fluid of the chambers must tend to cause an osmotic current from the sarcoplasm through the walls into the sarcomeres, so increasing the volume of their fluid contents. In this paper I will not discuss further the possibilities here suggested, but will merely point out some facts that seem to make it possible, and even probable, that such an osmotic current is the chief factor in the production of contraction. Firstly, the osmotic pressures that can be produced by even dilute solutions are very great: for example, the final osmotic pressure of a .1 p.c. solution of NaCl is said to be equal to that of a column of mercury 580 mm. in height. Secondly, owing to the minute size and great number of sarcomeres in any fibre, the area of mediate apposition of the fluid sarcoplasm and the fluid contents of the sarcomeres is enormously large. Thirdly, the two fluids are separated by membranes that are extremely thin, certainly not more than .1 μ in thickness. Fourthly, it has been shown that the substance of fatigued muscle, *i.e.*, a muscle saturated with the products of its own activity, has a greater osmotic equivalent than fresh muscle.¹

¹ I am engaged upon a series of experiments directed towards the gaining of more light upon this point.

If this suggestion be adopted as a working hypothesis, there can be given very plausible explanations in terms of the hypothesis of many of the most important properties of cross-striated muscle: for example, of its tone, elasticity, and extensibility;—and of many of the phenomena that accompany contraction and relaxation under various conditions: for example, the curve of relaxation and its variations, 'contracture,' 'rigor mortis,' water-rigor and its removal by 2 p.c. salt solution, summation of stimuli, tetanus, fatigue, and the effects of variations of temperature.

It is of interest to note that my account of the structure of cross-striated muscle affords a histological basis for speculations on the nature of the processes that produce contraction, published by other observers.

Thus, if Bütschli's (14) suggestion as to the nature of muscular contraction be slightly modified, it becomes applicable to the structure of cross-striated muscle as described in the first part of this paper. The essence of Bütschli's suggestion is that, by a change in chemical composition in some parts of a muscle fibre, the surface tension of hypothetical alveoli, to which he ascribes a peculiar arrangement of parts and supplementary discs, is altered, and the shape of the alveoli is altered as a result of this alteration of their surface tension. If, in the place of these hypothetical alveoli we put the sarcomeres, and suppose that it is their surfaces which suffer an alteration of surface tension, we may suppose the alteration to be of such a nature that the walls of the sarcomeres tend to become more convex to the sarcoplasm, and this would constitute a tendency to contraction of the sarco-styles.

D'Arsonval has attempted to explain the electrical variations exhibited by a contracting muscle as the result of alterations in the surface of contact between hypothetical discs in the muscle fibre and a surrounding fluid medium. We have seen that the surface of contact between the sarcomeres and the sarcoplasm in which they are embedded becomes very much reduced during contraction, and it may be suggested that this is either the cause or the effect of a negative variation of the electrical state at this surface.

I have gratefully to acknowledge the help received from Mr

C. G. Leftwich, of St John's College, in connection with various mathematical points. I have also received most valuable criticism and advice from Dr J. N. Langley and Dr T. Gregor Brodie, and to them my best thanks are due; and especially I wish to thank Prof. C. S. Sherrington for advice and encouragement on my first taking up this investigation.

LIST OF PUBLICATIONS REFERRED TO.

- (1) SCHÄFER, E. A., *Monthly International Journal of Anatomy and Physiology*, vol. viii.
- (2) ROLLETT, Alexander, *Bau des Quergestreiften Muskelfasern*, I. & II. *Theile*, *Wiener Denkschriften*, Bd. xlix.
- (3) VAN GEHUCHTEN, *La Cellule*, i., ii., et iv.
- (4) RETZIUS, *Biologische Untersuchungen*, 1891.
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- (7) HERMANN, *Handbuch der Physiologie*, Bd. i.
- (8) MELLAND, B., *Q.J.M.S.*, vol. xxiv.
- (9) BERRY HAYCRAFT, *Proc. Roy. Soc.*, vol. xlix.
- (13) SCHÄFER, E. A., *Proc. Roy. Soc.*, vol. xlix.
- (14) BUTSCHLI, *Schaum-plasma*.

DESCRIPTION OF THE PHOTOGRAPHS.

The photographs were taken with the 2 mm. apochromatic homogeneous immersion objective of Zeiss, with projection ocular and achromatic sub-stage condenser. The source of light was the oxyhydrogen lime-light in all except a few cases, in which the electric arc lamp was used. The magnification, except in the few cases where the magnification is given below the photographs, was a little more than 1000 diameters. To see all the details given in the photographs, it is necessary to examine them closely in a good light, preferably daylight. The parts which were accurately focussed, and to which I wish to draw attention, are indicated in the key to each photograph by a slight filling in of the outline sketch. It should be remembered that the 2 mm. apochromatic focusses very accurately in one plane only. Some of the photographs have suffered an unavoidable loss of definition in the processes of reproduction.

APPENDIX.

NOTE ON PROFESSOR RUTHERFORD'S ARTICLE.

An article by Professor Rutherford, dealing with the structure of the striated muscles of the crab, has appeared in the April number of this *Journal* since the above article was put into type. His description of a crab's muscle differs so much from my description of the muscle of the crayfish, that I have thought it well to reconcile the two descriptions, as far as possible, in this appendix. I have examined the muscles of the claw of the crab, and have found that they are like those of the crayfish in all essential respects. But they contain sarcostyles of a larger size than any that I have found in the muscles of the latter. These very large sarcostyles are correspondingly more resistant, so that it is easier to make good preparations from them, and to make out the details of their structure. The fibrillæ described by Professor Rutherford are the sarcostyles very much shrunken by the action of fixing reagents, and are, as he rightly suggests, hollow tubules; but the appearances presented by them in the shrunken state in which he observed them are very misleading, unless interpreted in the light of a knowledge of the structure of other types of muscle, especially of the insect's wing muscles. Professor Rutherford himself describes a slight swelling of each segment of the fibrillæ under the action of two per cent. acetic acid. This is only the first stage of a restoration to their normal shape that may be produced by the action of acids on them. Let Professor Rutherford, or anyone who wishes to convince himself of the essential accuracy of my description of this type of muscle, fix the claw muscles of a crab by immersion for twenty-four hours in two per cent. chromic acid solution, while the adductor muscles are kept fully extended in the manner already described. Let him then tease out a few slips of the muscles in water, put on a cover-glass, and, having found isolated fibrillæ, run in five per cent. acetic acid under the cover-glass. In addition to the slight degree of swelling that he has described, every degree of swelling of the sarcomeres up to the stage of restoration to their normal size and shape may be seen. In the shrunken fibrillæ the end discs α of the sar-

comeres are much crumpled, and during the swelling are slowly drawn out by the pull of the bulging side-walls of the sarcomeres. In specimens prepared in this way there occur many sarcomeres, with slightly abnormal shapes, but others may be found showing the form characteristic of every stage of contraction, exactly as I have described them in the sarcomeres of insects' wing muscles. In extended sarcomeres the γ , β , and γ discs can generally be clearly seen, and the γ discs can generally be seen to be bordered on either side by a very narrow band of brightness, that seems to be comparable to the halos bordering the α and β discs. And in these large sarcomeres (some are $20\ \mu$ in length) it is not possible to ascribe the appearance of the line γ to some illusory optical effect, as might be done in the case of small sarcomeres by those who refuse to accept the indirect evidence of their presence. I hope to prepare a series of photographs of these very large sarcomeres, that shall be more convincing than those accompanying this paper.

Prof. Rutherford, like all his predecessors in this field of research, has applied only the purely histological methods. There may be some who will look with suspicion on my account of the structure of cross-striated muscle because the investigation was begun with a preconceived idea as to the kind of structure to be found. To them I would point out that the number of competent, and even eminent, histologists who have devoted years of research to this subject without arriving at a definite conclusion, is enough to show that the purely histological methods used by them are inadequate to the solution of the problem, and to make it seem highly probable that without the use of hypothesis the problem never would have been solved.

THE ROLANDIC AND CALCARINE FISSURES — A
STUDY OF THE GROWING CORTEX OF THE
CEREBRUM.¹ By D. J. CUNNINGHAM, F.R.S., *Professor
of Anatomy, Trinity College, Dublin.*

FISSURE OF ROLANDO.

A STUDY of the beautiful work on cerebral anatomy which has been recently published by Professor Gustaf Retzius² has led me to examine anew the development and morphological bearings of the fissure of Rolando. In my previous examination of this sulcus, I came to the conclusion that the fissure of Rolando exhibited an example of the interrupted form of fissural development; and in the memoir³ which I published, I held that, as a general rule, it appeared in two pieces, and that this was to be regarded as the typical mode of development.

Dealing with the same question, Retzius expresses himself as follows:—"When the norma verticalis (of the cerebrum) is examined, we find that the sulci centrales are prolonged nearer to the upper border, either through direct growth or through the occurrence of a medial pit, which Cunningham has first observed, and which from the commencement is more or less directly connected with the lateral furrow. As a rule, the pit in question, if it occurs, has no independent formation, but first appears as a stronger medial deepening to the inner side of the growing central furrow. It is, moreover, not constant, and, further, does not exist so often as Cunningham supposes; still it is worthy of note."⁴

At first sight, there might appear to be very little difference between the views entertained on this matter by Retzius and myself. Still, from what he says, I think we may infer that he does not believe that the fissure of Rolando develops

¹ This paper was read at the June meeting of the Anatomical Society in Dublin, and was illustrated by a large number of photographs. It was prepared under the belief that the meeting was to be honoured by the presence of Professor Retzius, of Stockholm. Unfortunately, he was unable to be present, so as to take part in the discussion.

² *Das Menschenhirn*, Stockholm, 1896.

³ Cunningham Memoir No. VII., Royal Irish Academy, 1892.

⁴ *Vide* p. 23.

typically in an interrupted manner, and that when it does so the condition is to be looked upon as an occasional deviation from the usual and normal mode of development. Of course, some may think that the question at issue is one of very small moment. It is necessary, therefore, to insist at the very outset of this paper upon the fact that small points in cerebral development often possess a profound morphological and physiological significance. I believe this to be case in the present instance. It was this belief that induced me to go over the same ground a second time, and the result of my re-investigation has been that I am more than ever confirmed in the views which I originally expressed.

I possess forty-three cerebral hemispheres within the period during which we can study the earlier stages of the development of the fissure of Rolando. These we may divide into two groups, viz.—a group comprising those hemispheres which belong to the last week of the fifth month and the first three weeks of the sixth month; and a second group, in which may be placed those hemispheres which belong to the last week of the sixth month and the whole of the seventh month.

Group I.—This group includes twenty hemispheres. In five of these there is not a trace of the fissure. In eight the fissure is present in the form of a single faint oblique groove, the lower end of which is not far removed from the upper lip of the Sylvian fossa, whilst the upper end is separated from the superior border of the hemisphere by a wide area of cortical surface. In seven hemispheres the fissure is in two more or less distinct pieces. The lower piece in these cases is linear; the upper piece shows in the form of a slight depression—sometimes extremely feebly marked, but still perceptible. The majority of the hemispheres in which the Rolandic sulcus is double belong to the latter part of this period.

In the study of fissural development, it must always be borne in mind that the sulci owe their origin to the upheaval of the cerebral cortex on either side of the appearing sulcus, and that the gyri which are thus formed are the result of an exuberance of growth in localised areas. It is in this period, therefore, that the two central convolutions make their appearance, and towards the end of the sixth month they become very prominent. In a

large proportion of cases a conspicuous feature of the cortex at this time is a marked rounded elevation, which rises from the surface between the two pieces of the fissure of Rolando. As a general rule, this cortical eminence presents a faint furrow on the summit, which connects the two pieces of the sulcus and divides the elevation superficially into two portions, one of which belongs to each central gyrus. This must be looked upon as an area of intense and especially exuberant cortical growth, and in the adult brain it is afterwards represented by the portions of the central gyri which bound the superior genu of the Rolandic sulcus. As development goes on this cortical prominence is more and more completely cut into two by the deepening of the furrow which connects the two Rolandic pieces. The bridge of cortex which at first intervenes between the two pieces of the sulcus gradually sinks, and finally disappears from the surface, and the two exuberant lips of the fissure meet over it, and are usually tightly pressed against each other: indeed, as a rule, in no part of the sulcus are the bounding banks so closely approximated. No one who confined his investigation to a superficial examination of the sulcus of Rolando at this stage would ever suspect that it had originally been double.

I fully recognise that in my previous description, in using the word 'independent' in connection with the two pieces of the developing fissure of Rolando, I laid myself open to misconception. From what I have said, it will be seen that in the great majority of cases the two segments of the sulcus appear to be connected from the very first by a faint intervening furrow. On this point I accept the correction of Professor Retzius. Still, it must be observed that cases do occur in which the separation is complete, and amongst my series of specimens I have some which show this condition.

I have not seen a single instance of the compensatory furrow to which Retzius seems to attach some importance. The region where these compensatory furrows can be best studied is in the neighbourhood of the short limbs of the fissure of Sylvius. When one or other of these is absent, its place is not unfrequently taken by a most deceptive imitation of itself, differing from it only in the fact that it does not cut right through the operculum.

Group II.—In this group there are twenty-three hemispheres. As previously stated, these belong to a period ranging from the last week of the sixth month to the end of the seventh month. In twelve the fissure of Rolando is present in two more or less distinct parts: in four the exact mode in which the fissure has appeared is doubtful, but the presumption is in favour of two originally more or less completely separated parts; in seven the appearance presented by the surrounding cortex leads to the inference that in these cases the fissure had a single and not a double origin.

It is in the early part of this period that the two portions of the cortical eminence which intervenes between the two pieces of the developing Rolandic sulcus becomes particularly conspicuous.

But, quite apart from the study of the different phases which are assumed by the sulcus as the cortex grows and the central gyri take shape, there are reasons which would almost lead us by analogy to infer that the typical mode of development of the Rolandic fissure is by two parts. The præcentral, the Rolandic, and the postcentral sulci constitute a furrow-group, the three members of which cannot be dissociated from each other. They are well termed the three radial ‘Primärfurchen,’ and they constitute one of the most characteristic features of the developing human brain. Of these, the præcentral and postcentral sulci unquestionably develop in two pieces, and it is natural to suppose that the Rolandic furrow should show a similar tendency.

Evidence as to the double origin of the Rolandic fissure is likewise present in the adult brain. If we open up the sulcus widely, we find in the neighbourhood of the superior genu either a distinct deep annectant gyrus, or a shallowing of the furrow with a strong interlocking of the adjacent walls. The annectant gyrus and the shallowing represent the bridge of cortex which in the early stage separates the two original parts of the fissure. The specially strong dovetailing of the two central gyri in this situation indicates the exuberance of cortical growth which from a very early period is manifest at this point, and which in the young growing cerebrum takes the form of the marked prominence already alluded to.

The foetal brain does not completely fill up the cranial capsule.

A space of some width, occupied by subarachnoid fluid, exists between the surface of the cerebrum and the wall of the cranium. Consequently, as particular areas of the cortex grow and foreshadow the future gyri, they suffer no restriction, and they take the form of eminences which rise from the general surface level of the cerebral hemisphere. As growth goes on, however, and as the brain gradually assumes a bulk more nearly in accord with the cavity of the cranium, the space for extension becomes more limited, and the gyral elevations are pressed together and assume the ordinary convolutionary forms. So far, then, we can say that the enclosing skull capsule affects the surface pattern of the cerebrum. And by allowing it this amount of influence, we can account for the difference in the inclination of the furrows in brachycephalic and dolichocephalic heads. Where a marked exuberance of growth exists, as in the neighbourhood of the superior genu of the Rolandic sulcus, the redundant cortex takes the form of deep interlocking gyri which spring from the opposed surfaces of the convolutions bounding the fissure.

It is a matter of extreme interest to note that in certain rare cases the deep annectant gyrus which is occasionally seen at the bottom of the Rolandic sulcus at the level of the superior genu remains permanently on the surface, and in the adult brain completely separates the two original pieces of the sulcus from each other. This condition was first observed by Wagner¹ in the brain of Prof. Fuchs. Heschl,² who investigated the matter in a very thorough manner, found the interrupted form of the fissure only six times in 2174 hemispheres. Eberstaller³ met with the anomaly twice in 200 brains. Zernoff⁴ has figured and described one case; Féré⁵ has seen two examples of the condition; whilst at a recent meeting of the Anatomical Section of the Royal Academy of Medicine in Ireland, Prof. Fraser announced that a case had occurred in his department, but he did not exhibit the brain, nor

¹ *Vorstudien zu einer künftigen wissenschaftlichen Morphologie und Physiologie des menschlichen Gehirns als Seelenorgans*, 2 Abh., 1862, Tab. 1, p. 14.

² "Die tiefen Windungen des Menschlichen Grosshirns und die Überbrückung der Centralfurche," *Wiener Medicinischer Wochenschrift*, 1877, No. 41.

³ *Das Stirnhirn*, 1890.

⁴ "A rare case of Change of Form of the Rolandic Furrow and Central Convolutions," Moscow, 1887.

⁵ "Anomalies du Cerveau," *Bulletin de la Société anatomique de Paris*, 1876.

did he show any illustration of it. As for myself, although I have been on the constant outlook for an example of this interesting form of the fissure of Rolando, I have never been so fortunate as to secure a brain in which it was present. In one of the negro brains in my possession, however, a very near approach to the complete separation of the two parts of the sulcus is to be seen. The deep annectant gyrus is almost, but not quite, on the surface.

This rare anomaly of the fissure brings out more forcibly the analogy which I believe to exist between the Rolandic, præcentral, and postcentral sulci. As I have said, it would seem that the typical mode of development of each of these furrows is in two parts, viz., a long lower and a short upper part. As a rule, the two portions of the præcentral sulcus remain permanently separate, and constitute the sulcus præcentralis superior and the sulcus præcentralis inferior of descriptive anatomy. In the case of the postcentral sulcus the tendency is for the two pieces to run into each other and fuse, although the point of junction is usually indicated at the bottom of the furrow by the presence of a deep annectant gyrus. Still, in 19 per cent. of the hemispheres which I have examined the two pieces of the postcentral sulcus remain permanently separate and distinct, and this is the condition which, in his original description of the intraparietal furrow, Sir William Turner regarded as typical. In the Rolandic sulcus, the connection between the two pieces is still more intimate. In many cases, and even not unfrequently in the developing brain, the double nature of the sulcus is not recognisable. Again, in hemispheres in which the furrow has undoubtedly originated in the typical manner, the fusion may become so complete that the only trace of the junction is a slight shallowing of the sulcus and an interlocking of the bounding gyri at the point of junction. In only .03 per cent. (Heschl) of cases do the two pieces remain permanently separate.

Heschl, in the article already quoted, insists upon the importance of a close study of the deep annectant gyri of the human brain, and carried out a most elaborate and thorough investigation into the various conditions presented by the deep gyrus which is occasionally present at the junction of the upper and middle thirds of the fissure of Rolando. As Retzius does not allude to his results, I am induced to reproduce them here, seeing

that they have a direct bearing on the question at issue. Heschl says:—"Ich habe die von mir nach und nach aufgefundenen Tiefen-Windungen mit griechischen Buchstaben bezeichnet und zwar die in Rede stehende mit α . Es musste nun weiter geschlossen werden, dass α in allen Graden der Ausbildung vorkommen müsse und dass ein Fall von totaler Unterbrechung von C durch dieselbe nicht gar lange bei systematischem Nachsuchen auf sich warten lassen werde, das bestätigte sich denn auch und ich gebe im Nachstehenden das Resultat meiner Aufzeichnungen. Ich fand Folgendes:

| Gehirne. | C. ganz überbrückt. | | $\alpha \frac{1}{3}-\frac{1}{2}$ hoch. | | $\alpha \frac{1}{2}-\frac{2}{3}$ hoch. | |
|------------------------|---------------------|--------|--|--------|--|--------|
| | rechts. | links. | rechts. | links. | rechts. | links. |
| Männliche 682 Fälle | 3 | 2 | 9 | 16 | 19 | 20 |
| Weibliche 455 Fälle | 1 | — | 17 | 25 | 17 | 19 |

N.B.—*Die Fälle mit ganz geringen Erhebungen sind nicht notirt worden.*"

Eberstaller,¹ who is, without exception, the most acute observer who has of recent years taken part in cerebral investigation, is still more fully impressed with the fact that the deep gyri of the human brain convey lessons of the most far-reaching importance. Prior to his investigations, other authors, such as Gratiolet, Heschl, and Wernicke, had called attention to the deep gyri in certain restricted regions of the cortex, but Eberstaller lays stress upon the fact that they are met with in all localities, and further, that they exist in all stages of formation, "from tooth-like interlocking crenations or weak projections at the bottom of a furrow, to a completely superficial sinuous bridge, which crosses a furrow which in other circumstances is single." I am doubtful if we

¹ "Zur Oberflächen-Anatomie der Grosshirn-Hemisphären," *Wiener Medizinische Blätter*, April 1884, No. 16.

should in all cases class the interlocking tooth-like gyri of the adjacent lips of a furrow with deep annectant gyri. This dovetailing within a fissure may have another explanation, and be due rather to an exuberant growth of the cortex on either side of this portion of a furrow.

I have been led to refer to the general question of deep annectant gyri because a close study of the memoir of Retzius has left on my mind the impression that the author somewhat under-rates their morphological value. With Eberstaller, I hold the view that they constitute one of the great and distinctive characters of the human brain. In the uniform smooth-walled fissures of the cerebrum of a lower ape they are rare, so rare that, except in the case of the 'Affenspalte' and the callosomarginal sulcus, they might almost be disregarded. In the Anthropoid ape they are encountered in certain fissures, such as the 'Affenspalte,' the intraparietal, the Rolandic, the callosomarginal, etc. In man, on the other hand, they are found in the majority of fissures and on all aspects of the brain, and their presence would seem to indicate the decided and special tendency which the human brain presents towards the interrupted form of fissural development; consequently those who study the cerebral surface must subject the interior of the sulci to the closest scrutiny.

The views which I entertain regarding the fissure of Rolando are concisely expressed in the following summary:—

1. The typical mode of development of the sulcus of Rolando is in two more or less separate and distinct pieces.
2. Judging from the specimens in my possession, this would likewise appear to be the more usual mode of development. At the same time, it would be wrong to deny that in several cases the sulcus appears to develop in one single piece, whilst there are other cases in which, owing to the early close closure of the lips, it is impossible to say whether the fissure has originated in a single or a double fashion.
3. The double or interrupted mode of development of the Rolandic sulcus indicates a parallelism with the mode of development of the two other furrows of the same group, viz., the præcentral and the postcentral sulci.

This furrow group constitutes one of the leading peculiarities of the primate cerebrum.

4. The interrupted form of fissural development bespeaks a higher type, and is peculiarly characteristic of man.

But it appears to me that a physiological interpretation can be put upon the different phases which are assumed in the process of development by the Rolandic sulcus and its two bounding gyri. The cortical elevations which rise on the surface of the cerebrum, and which foreshadow the future gyri, are, as we have already stated, undoubtedly due to exuberant growth in localised areas. But functions of different kinds are localised in different districts of the cortex. It is true that these functional areas overlap each other to a considerable extent, but the central part of each may be considered to represent the portion of the cortical functional area in which there is the greatest purity of function, and in which the functional activity is the most intense. There cannot be a doubt that functional development and cortical growth go hand in hand; and that, when we see an area of the cortex rising up to form an eminence, we may conclude that the growth in the area concerned bespeaks potential functional activity of an acute kind.

When we apply this to the fissure of Rolando and its two bounding gyri, the appearance of the sulcus in two parts may be explained by the fact that in connection with its lower part are developed the upper limb centres, whilst grouped on either side of its upper third are the lower limb centres. The earlier appearance of the lower part of the fissure may also be accounted for by the fact that the upper limb buds out before the lower limb, and throughout the whole of its early development keeps steadily in advance of the lower limb. It is reasonable to suppose, therefore, that the centres for the upper limb will appear before those for the lower limb, and in this way map out, in the first instance, the lower part of the Rolandic sulcus.

The high elevation which in the early cerebrum lies between the two pieces of the Rolandic sulcus, and which afterwards corresponds to the portions of the central gyri which bound the superior genu of the fissure, occupies very much the position at which the ankle and foot centres merge into the

shoulder centre. It is difficult to account for the great exuberance of cortical growth at this spot, but perhaps those who are engaged in localisation research may have some explanation to offer. Another point which requires consideration consists in the greater growth energy of the postcentral gyrus than the præcentral gyrus. In the lower part of the fissure, as Heschl and Eberstaller have pointed out, the posterior central convolution becomes actually to some extent opercular, and overlaps in some degree the anterior central convolution. In the foetal brain, before the gyral elevations become pressed together, and all assume a more or less uniform surface-level, the prominence of the postcentral gyrus, due to redundant growth, is very marked. Owing to the higher functions which the upper limb and hand have to perform, it is natural to expect that the portions of the gyri in which their centres lie should show a greater exuberance than the portions of the gyri allotted to the lower limbs. To this circumstance may be due the opercular character of the posterior central convolution in the region of the arm centres, and also the great depth of the middle third of the fissure of Rolando.

I have not considered it necessary in the present instance to figure the different stages of the development of the fissure of Rolando, seeing that in my memoir on the cerebral surface I have given a large number of illustrations of the Rolandic area at different periods of growth.

CALCARINE FISSURE.

Retzius also hesitates to accept certain of the views which I have advanced in regard to the development and morphology of the calcarine fissure. He says: "In the latter half of the fifth month, and still more in the sixth month, the calcarine and parieto-occipital fissures grow outwards towards the mantle-border, and not unfrequently it happens, but by no means as a rule, that behind the first rudiment of the calcarine fissure a new small furrow element arises, which gradually unites with the front element and represents the outer part of the calcarine fissure in the adult brain. This appearance, upon which Cunningham lays considerable stress, sometimes occurs; still, I

do not believe that such a fundamental difference between the fore and hinder parts of the fissure can be recognised as Cunningham sees. The front part grows at least as often without a hinder addition, and forms itself its hinder part."

A careful study of my specimens has shown me that I have little to add to what I have already written on this subject; and I also find that, even with Retzius' great atlas before me, I do not wish to modify any of the statements I have previously made. The matter is not so simple and straightforward as Retzius seems to think. There is no part of the cerebral surface which is more puzzling in its mode of development, and the subject cannot be dismissed in the summary way adopted by Retzius. It was only after several years of study and much groping in the dark that the views I now entertain took form. A considerable difference will be observed between the statements made on this subject in the article which I published¹ on the complete cerebral fissures in 1890 and those which I made two years later in my memoir on the cerebral surface. It is very possible that Retzius' views may undergo a similar process of evolution; and to hasten this result, I have sent to him photographs of several of the more characteristic of my specimens.

The anterior portion of the calcarine fissure (*fissura calcarina anterior*) is formed at an early date, and is a complete fissure. In the adult its hinder part is responsible for the elevation in the posterior horn of the lateral ventricle, which is known in descriptive anatomy as the hippocampus minor, or the calcar avis. The posterior portion of the fissure (*fissura calcarina posterior*) appears later, and is to be looked upon as a secondary sulcus, added on to the primary fissure. Anyone who opens up the adult fissure can see the difference between its two parts, and several of the figures given by Retzius of the adult brain afford evidence of this. The posterior secondary part of the calcarine fissure is typically developed in two pieces. These usually appear as two dimples or depressions, of which one is placed on the extreme point of the occipital pole, whilst the other lies midway between this and the primary fissure. Ultimately, furrows connect the several parts; and as these deepen, the adult continuous form of the fissure is

¹ *Journal of Anatomy and Physiology*, vol. xxiv. p. 309, 1890.

attained. Under ordinary circumstances, the intervening portions of cortex, which are thus borne down into the interior of the fissure, can be distinguished in the adult brain in the form of two deep annectant gyri, which I have termed the anterior and posterior cuneo-lingual gyri. Very frequently the terminal depression or dimple, which, as a rule, joins with the remainder of the fissure, and forms its forked extremity, remains separate, and the posterior cuneo-lingual gyrus is retained on the surface. The significance of this piece of the fissure appears to have escaped the attention of Retzius. In plate xx. figure 6 he figures it, and calls it in the letterpress attached to the plate a compensatory furrow. So it is in a way, but it is a compensatory furrow which is almost constantly present, and which in cases of typical development is linked on to the calcarine fissure as its forked extremity. In plate lxxxii. fig. 2, and plate xciii. fig. 2, Retzius gives representations of the adult cerebrum, in which this piece of the secondary fissura calcarina posterior remains separate. It is cut off from the rest of the fissure by a superficial posterior cuneo-lingual gyrus.

It is evidently to the anterior of the two depressions which go to form the hinder secondary part of the fissure that Retzius refers when he speaks of a 'new small furrow rudiment,' which is not unfrequently present, 'but by no means as a rule.' I have never asserted that this was invariably present, but I do insist that at the stage of evolution at which the human brain has reached it is to be regarded as a typical element of the fissure. Further, in the large majority of foetal brains of this period which I possess, it is clearly and distinctly seen. In the figures given by Retzius the early stages of the development of the calcarine fissure are very beautifully illustrated, but in several of the figures the later stages are not so well represented. It is possible that in the process of preparation some of the fainter markings have been obliterated.

So far, we have dealt to a large extent with matters of fact, and therefore I have spoken with a considerable amount of confidence; but the morphological views which I have advanced in regard to the homologies which exist between the calcarine fissure of man and that of the ape are to some extent speculative, and it is not to be expected that all observers will regard the question from the

same standpoint. I am not surprised, therefore, that Retzius should express himself doubtful on this matter. It would have been more satisfactory, however, if he had discussed the evidence, and had made some attempt to explain the several anomalous conditions which so frequently occur in this region, and many of which I believe to represent reversions to an apelike condition of the furrow.

CASE OF ANOMALOUS KIDNEY AND URETER.

By T. W. P. LAWRENCE.

THE specimen of which this is a description was taken from a patient under the care of Dr Bradford, to whom I am much indebted for kindly placing it at my disposal.

The patient, a boy *ætat.* 16 years, died from tuberculous meningitis. At the post-mortem examination the left kidney was found to be hypertrophied (weighing $7\frac{3}{4}$ ounces), but no other abnormality was present on that side. On the right side the suprarenal body occupied the normal position, but the kidney and renal artery were apparently absent. On dissecting out the branches of the lower part of the aorta, however, a small renal artery was found, measuring scarcely 2 mm. in diameter, and rather more than an inch in length (fig. 1). It arose from the right side of the aorta, at a point half an inch above the bifurcation, and passing transversely outwards, ended by dividing into five branches to the kidney. The measurements of the kidney, which was situated in the lower lumbar region, were: length, 1 inch; breadth, $\frac{2}{3}$ inch; thickness, $\frac{1}{4}$ inch. The shape was somewhat triangular; the upper part of the organ tapering to a point corresponding to the point of termination of the renal artery, and receiving the branches of that artery. Two of the branches, situated rather anteriorly in relation to the others, passed almost immediately into the apex of the kidney: two of them passed down the inner and outer borders, and entered the organ about one-fifth of its length down; the remaining branch passed down the middle of the postero-internal surface, and entered at about the mid-point of the surface. These five branches were in close apposition to the upper part of the organ, which was thin and flattened in comparison with the more rounded, thicker, and somewhat lobulated lower part. From the postero-internal surface issued two pairs of tubes: of the inner pair one tube arose from near the upper extremity, the other from near the lower angle. The outer pair arose one tube above the other, and much closer together, from near the middle of the surface. These tubes united to form two

tubes of about 2 to $2\frac{1}{2}$ mm. in width, which on being traced

B



U... b

FIG. 1. (nat. size). A, Posterior. B, Anterior.

downwards were found to pass *behind the common iliac vein and*

the common iliac artery, and after a course of one inch and a quarter, united to form a single tube, measuring 4 mm. in diameter at its upper part. This tube (*a*), thick-walled, especially at its lower part, is to be regarded as the pelvis of the ureter: it passed down in the pelvic cavity towards the base of the bladder, became somewhat narrower at its middle part, but wider again and also flattened and twisted in its lower third, where it had a width of 6 mm. After a course of $3\frac{1}{2}$ inches, it terminated at the level where the vas deferens crosses the ureter, by abruptly contracting to a narrow thin-walled tube, measuring not more than $1\frac{1}{2}$ mm. in width. Of the latter tube (*b*), which is to be regarded as the ureter, only $\frac{1}{4}$ inch is present in the specimen; the condition of the terminal part of the ureter, with its orifice, together with the internal appearances of the bladder and urethra, were not observed.

The testicles were normal, also the vasa deferentia and lower part of the bowel: there were no other abnormalities present in the body.

The causes of congenital atrophy of the kidney are anatomical or pathological: hypoplasia or incomplete development and congenital smallness of the renal artery are given as anatomical causes.

The present specimen is of interest in four respects: (1) as enabling us to locate the primary cause of the atrophy, in this instance, in the ureter, mainly if not entirely, and consequently (2) as rendering clearer the relationship between atrophic conditions of the kidney and the malformations of the genital canals and lower bowel so frequently found associated with them, through the close anatomical connection of the ureter with those structures, in the cloacal region; and (3) as suggesting the possibility of an intimate relationship between certain forms of displacement atrophy and absence of the kidney.

Assuming that the view regarding the tube *a* as renal pelvis and the tube *b* as ureter is correct, it follows that the ureter is abnormally short, and that the lower end of the renal pelvis has been held down close to the bladder during the growth of the trunk. On the other hand, the kidney, although a 'low-level kidney' (that is, one receiving its main blood-supply at a lower level than normal), has not been drawn down out of the lumbar

region by the shortness of the ureter; consequently, the distance between kidney and ureter has been abnormally increased, and the calices and renal pelvis have been subjected to a longitudinal strain. As evidences of such tension in the pelvis are its elongation to a length exceeding what is found even in the adult, and the narrow tubular form which it has taken. (The spiral twisting of its lower end is probably due to the inequality of tissue growth which normally occurs between the upper and lower borders of the pelvis, causing the former to be longer than the latter.) Also, an increase in fibrous tissue has taken place in the tissues of the pelvis, and this may be regarded as additional evidence of tension, fibrous or fibro-elastic tissue being that which is developed regularly wherever a stretching force has to be borne.

The structure opposing the downward tension is the renal artery, not only at its point of origin, but probably also along its whole length, through pressure against the hinder abdominal wall, such pressure in all probability being exerted by the postero-internal surface of the upper part of the kidney also. The longitudinal strain on the renal artery has resulted in great thickening of the external coat (fig. 2).

At the kidney the first effect of the traction would be felt at the point of entry of the lowest arterial branch: strain on the branches above this would for a time be relieved by tilting inwards of the upper end of the kidney (with a resulting tendency to bring the arterial branches into one plane, as in the specimen), by the strain at first being transmitted through the lowest arterial branch, and also by a yielding of the renal tissues in such a way that the upper part of the kidney failed to fold downwards to enclose the upper end of the sinus, the highest arterial branches consequently passing directly into the upper extremity of the gland. (Possibly, also, some actual stretching of the kidney-substance may have taken place.)

FIG. 2.

The portion of kidney lying below and outside the insertion of the lower calices obviously does not lie in the line of tension, and this part has folded round to form the lower part of the sinus in the normal way, as a section shows. The point where tension would be most severely felt by the arteries is evidently where the lowest branch crosses the lowest calyx, where no tilting of the kidney or yielding of its substance could take place. Consequently, on microscopical examination of the lower and outer part of the kidney,—lying outside the line of strain, but the arterial supply of which must have been severely influenced,—a condition of simple and complete atrophy is found (fig. 3): the

FIG. 3.

proper kidney-substance is absent, and in its place is a convoluted layer of dense connective tissue, almost granular in appearance, and devoid of vessels and tubules.

The upper portion of the kidney, lying in the line of strain, and in which the arterial supply is less severely affected, exhibits (fig. 4) relatively great increase of connective tissue, a considerable degree of vascularity, and renal tubules in scanty numbers. No formation of pyramids is evident, but the tubules, apparently directly continued from the calices, undergo branching as their course towards the surface of the organ is pursued, and terminate in a narrow layer of small irregular tubules, without apparent lumen, lying close beneath the capsule of the gland. No convoluted tubules are present, nor any signs of Malpighian glomeruli.

The presence of tension is therefore evidenced by several facts,

and the atrophy or total disappearance of all trace of renal tissue in a large part of the organ may be attributed to it: whether the absence of convoluted tubules, glomeruli, and pyramids in the remaining part of the kidney is due to the same cause, or to defective development affecting not only the ureter but also the upper ramifications of that tube, hindering the junction of the connecting tubules with those parts of the gland contributed by the intermediate cell-mass, with resulting disappearance of the latter, is not evident.

FIG. 4.—*b*, vessels; *t*, tubules; *s*, stroma; *c*, capsule.

The factors producing the tension in the specimen are the normal growth of the trunk and the defective development and growth of the ureter ('normal development' being defined as the elongation upwards of the tube from the base of the Wolffian duct to the normal kidney-level: 'normal growth' as the elongation of the tube in correspondence with the elongation of the trunk, so that its length shall throughout the period of body-growth be exactly that required by the already determined and fixed kidney-level).

When the upward development of the ureter is defective in the foetus (fig. 5) (A), but subsequent growth of the tube is adequate,

a typical case of low-level kidney results, the only deformities present being the low position of the kidney and its arteries, and shortness of the otherwise normal ureter. (B) The extreme instance of this form would be failure of development of the ureter altogether, with consequent absence of kidney and ureter in the adult. When the upward development of the ureter is defective in the foetus (A), and subsequent growth of the ureter



A

B

C

D



E

F

G

FIG. 5.

defective also, traction (represented by an arrow) is exerted on ureter and kidney (C), and results follow as in the specimen exhibited, viz., low-level and atrophic condition of kidney, with evidences of stretching in the excretory duct. An exaggerated form of this is where, with atrophied kidney, no traces of ureter are present except quite at the lower extremity (D). When the

upward development of the ureter is complete (E), but subsequent growth of the ureter defective, traction comes into play, as in the last example, but necessarily greater, and through the conceivable form (F), with atrophic kidney at the normal level, and greatly stretched excretory duct, is reached that form of absent kidney where a portion of the lower part of the ureter is present of varying length, and sometimes ending above in a fusiform dilatation, probably representing the lower part of the renal pelvis (G). The extreme instance of this form would be complete absence of both kidney and ureter.

The anomalous position of the ureter behind the iliac artery and vein does not appear to have been observed hitherto, and no explanation is offered of its mode of origin.

NOTES ON THE MYOLOGY OF A NEGRO.¹ By THOMAS
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College, University of Glasgow.*

DURING the present session I had the opportunity of dissecting a negro, a well-developed muscular male, 5 feet 10 inches tall, and said to be 34 years of age. He was evidently a pure-bred negro, but as he appeared on the certificate under the denomination of 'Joe Smith,' I could obtain no clue from his name as to his tribe or country.

From what we already know as to the myology of the lower races of men, it is probable that if the Negro differ from the European in his myology, it is only in the relative frequency of variations common to both. Although there seems reason to believe that myology cannot provide any absolute ethnological data, the question is still open whether or not negro myology reveals a greater relative frequency of variations which may be regarded as atavistic.² I determined, therefore, to note carefully any deviations from the recognised European average in each muscle as it was exposed, and I desire to put on record the notes of my dissection, simply as a single contribution to the sum of our knowledge of the subject. Many of the varieties are well recognised as being of not infrequent occurrence in the European, but for the sake of comparison, even at the risk of seeming to enter on unnecessary detail, I give a complete account of all deviations from the standard met with. Every muscle not specially mentioned conformed exactly to the description given of it in *Quain's Anatomy*, 10th edition; and I may add that, to eliminate the personal equation, I have accepted the descriptions in that work as the standard of normal European myology.

I. *Head and Neck.*

The insertion of the *Trapezius* on to the clavicle is prolonged forwards, to meet the outer border of the sterno-mastoid. The insertion of this abnormal slip is to a certain extent independent, being attached

¹ Read before the Anatomical Society of Great Britain and Ireland, 12th March 1897.

² Compare remarks by Wiedersheim in "The structure of Man an index to his past history," English translation, Macmillan & Co., 1895, pp. 121-122.

by an aponeurosis separated from the outer part by an angular interval, through which some branches of the descending cervical nerves pass. The clavicle is pierced by a large branch of the same series of nerves.

The *Levator anguli scapulæ* sends a slip from its lowest head downwards to join the *Serratus magnus*.

The right *Digastric* has a slip passing over the middle line, to be attached to the lower border of the jaw on the opposite side, outside the symphysis.

II. *Trunk and Abdomen.*

Pectoralis major had one digitation fewer, the *Serratus magnus* one digitation more than the average.

There is no *Sternalis*, *Pectoralis quartus*, or *Dorso-epitrochlearis* muscle.

All the other muscles conformed to the conventional descriptions.

III. *Intrinsic Muscles of the Upper Extremities.*

Deltoid is much segmented on both sides, and on the right side the part arising from the spine of the scapula is in large measure independent.

Biceps, on left side, has a humeral head, arising just below the insertion of the coraco-brachialis.

Brachialis anticus, on the right side, is divided into two laminae, quite distinct from one another, both ending on a tendon, inserted as usual. On the left side the two laminae are partially fused. The superficial layer arises from the humerus below and on each side of the deltoid impression, the deep lamina from the anterior aspect of the shaft, and intermuscular septa.

The *Pronator radii teres* of the right side has no coronoid head.

Flexor carpi radialis brevis is present in the left arm. The fibres of the *Flexor sublimis digitorum*, on the radial side, are attached to a long slender tendon, which springs from the lower end of the oblique line. At the junction of the middle and lower thirds of the forearm the tendon becomes free, and gives rise to a fusiform belly, which again ends in a tendon attached to the anterior annular ligament and trapezium.

Flexor profundus digitorum, on right side, arises in two parts,—an ulnar, arising from the ulna and interosseous membrane; and a radial, arising from the radius internal to *Flexor longus pollicis* from the coronoid process to the *Pronator quadratus*, and from the interosseous membrane. From this radial head two tendons spring, which join under annular ligament, and go to the index finger. The tendons from the ulnar head go to the middle, ring, and little fingers.

The *Lumbricals* are small: i. and ii. arise from radial side of the tendons only.

Extensor communis digitorum of left side distributed its tendons normally, but the *Ext. minim. digiti* gives a tendon to the ring finger, in addition to its two usual slips to the little finger.

On the right side, the *Extensor communis* gives rise to four tendons, which pass together under the annular ligament. *The first* goes to the index, and is joined by a slip from the second, which springs above the wrist. *The second* goes to the middle finger, but divides on the back of the carpus into two parts. *The third* tendon to the ring finger is attached to the ulnar segment of the last by a broad expansion, which also receives an accessory slip descending from the forearm. *The fourth* tendon is on a deeper plane, sends a slip to the middle and another to the ring finger, and a third which goes to the little finger, and is joined by the tendon of the *Extensor minimi digiti*. The latter has its usual second slip to the ulnar side of the expansion of the tendon.

The *Extensor ossis metacarpi pollicis* divides into two bellies, each ending in a tendon. The main tendon is inserted into the base of the metacarpal bone; the other divides into two, one attached to the trapezium, the second joins a fusiform muscular belly forming an accessory head to the *abductor pollicis*.

Muscles of the hand are exceptionally powerfully developed.

Palmaris brevis is composed of coarse fasciculi, and is $1\frac{1}{4}$ in. broad.

Abductor pollicis has an accessory head from the *Extensor metacarpi pollicis*, a second head from the tuberosity of the Scaphoid, and a third, quite independent, from the annular ligament. *Opponens* arises from radial side of Trapezium and annular ligament.

Outer head of Flexor brevis arises from the ridge on the Trapezium, and annular ligament closely united with *opponens*.

Inner head of Flexor brevis arises from the Trapezium, base of 1st metacarpal and sheath of radial flexor.

Adductor pollicis is divided into two parts:—(1) *Obliquus*, from bases of 2nd, 3rd, and 4th metacarpals, os magnum, anterior carpal ligaments, and also from proximal third of the shaft of the 3rd metacarpal,—this latter origin being separated from the former by the deep branch from the ulnar nerve. (2) *Transversus*, arising from the distal two-thirds of the shaft of 3rd metacarpal, the fibro-plate of the metacarpo-phalangeal articulation, and by a distinct slip from the head of the 2nd metacarpal above the condyles.

On the dorsum of the hand a muscular slip arises from the ligaments on the back of the carpus and base of 3rd metacarpal bone, and joins below the 2nd dorsal interosseous muscle.

Lower Extremities.

The *Psoas* arises as usual, and there is no *Psoas parvus*.

The *Iliacus* has on the left side a special slip from the anterior inferior spine, which is partially separate, and attached below and in front of the remainder of the muscle.

Gracilis has an extensive origin from the whole length of the pubic arch.

Adductor longus and *brevis* are normal.

Adductor magnus is much segmented, and is symmetrical. There is (1) an anterior slip arising from the body of the pubis, external to

adductor brevis, and inserted into the back of the femur, behind the pectineus; (2) a slip from the pubic ramus and part of ischial ramus inserted behind adductor brevis into back of femur; (3) a thick mass from the ischial ramus and tuberosity, which spreads out to be inserted into the linea aspera, the hindmost fibres ending 13 cm. above the knee on the internal intermuscular septum, which is thickened to form a prominent band attached below to the adductor tubercle (see figs. 1 and 2).

The so-called 'opening in the adductor magnus' has thus the appearance of an opening in the fascia rather than an interval in the attachment of the muscle.

Obturator externus on the left side is cleft by a branch of the obturator nerve into two fasciculi.

Quadriceps extensor.—The *rectus* is normal.

The arrangement of the *Crureus* and *Vasti* deserves special attention, owing to the rôle attributed to the crureus and vastus externus by Manouvrier¹ in modifying the shape of the femur. They are arranged just as in the European, except that the vastus externus cannot be separated from the crureus so completely as usual. The vastus externus is attached to external lip of the linea aspera, the gluteal line, the shaft of the bone below and in front of the trochanter major as far as the tubercle of the femur. The crureus arises from the tubercle of the femur, the outer and anterior surfaces of the shaft, as usual. Thus the origins of these muscles are not lowered.

Gluteus maximus is normal, the femoral insertion perhaps rather restricted, and the lower fascial insertion rather stronger than usual.

Gluteus medius is fused with the minimus anteriorly, and the combined fibres arising from the outer side of the anterior superior spine, the notch below, and the outer side of the anterior inferior spine form a separate strong fasciculus, which is attached below to the superficial aspect of the tendon of the minimus, to the lower and anterior part of the oblique line on the great trochanter, and is prolonged on to the shaft of the femur, being arched over here by the fascia covering the vastus externus.

Gluteus minimus is connected behind with the pyriformis, and is inserted into the capsule of the joint, the upper border of the trochanter, and its anterior face.

The *Hamstrings* arise normally from the ischial tuberosity.

Semi-tendinosus is normal.

Semi-membranosus is a powerful muscle, inserted as follows:—Its tendon expands into a strong aponeurosis, attached anteriorly by a rounded tendon into inner side of the internal tuberosity. Externally, it passes over to the external condyle, on a level with the back of the condyles. Above, it is continuous with the tendinous inner head of the gastrocnemius. Below, it is strongly attached to the back of the internal tuberosity, and prominent tubercle bounding the popliteal notch, and to the shaft of the tibia behind the internal lateral ligament.

¹ Manouvrier, "Deux Étude sur Pithecanthropus Erectus," *Bull. de la Soc. d'Anthrop. de Paris*, t. sixième, iv. serie.

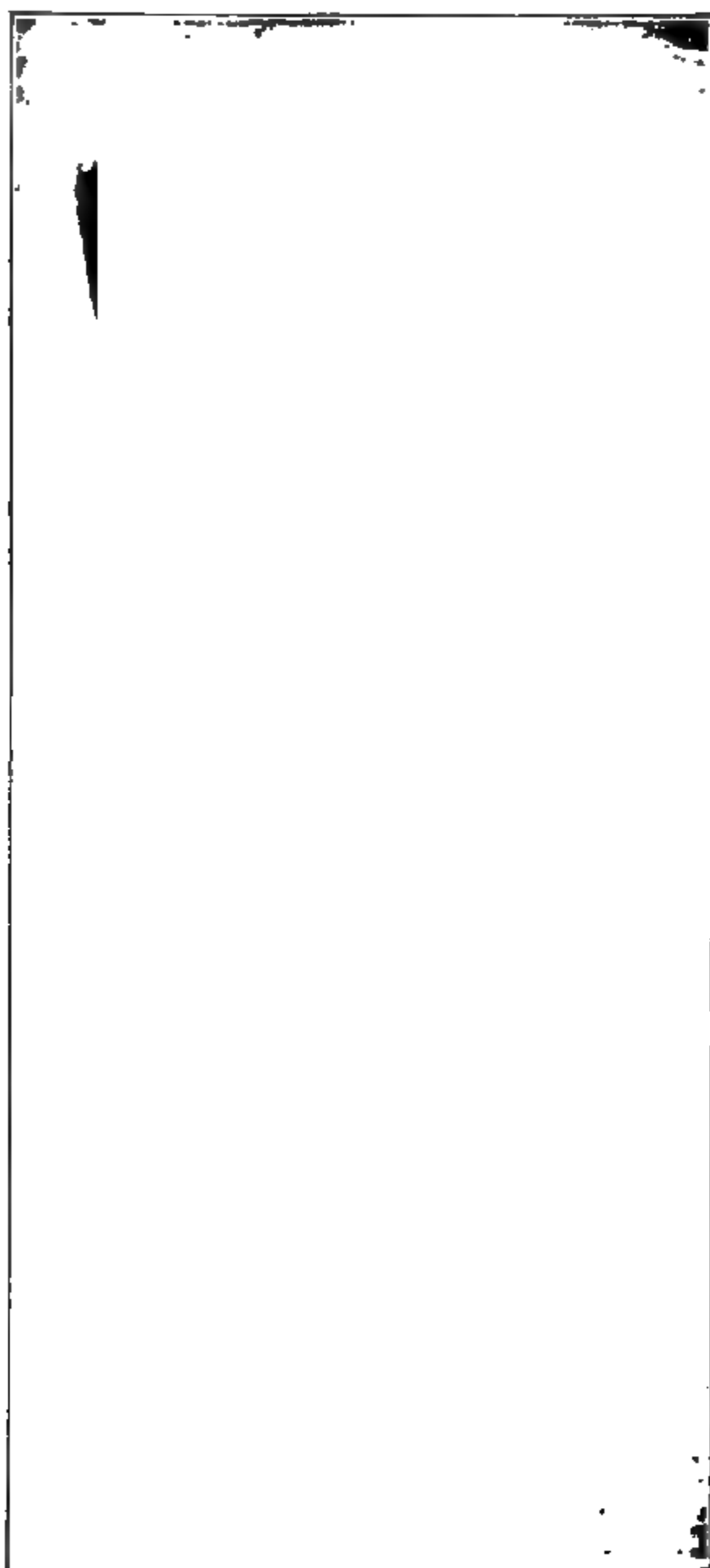
FIG. 1.



T.H.B. del. ad nat.

Left Side.—Long head of biceps and accessory fasciculus drawn aside. Femoral head is seen arising from the popliteal surface of femur, coming in contact to inner side with vastus internus, and below with tendinous inner head of gastrocnemius. Fascia over vastus internus left partially intact.

Fig. 2.



T.H.B. del. ad nat.

Right Side.—Long head of biceps and accessory fasciculus drawn aside. Femoral head cut through to show insertion of accessory fasciculus.

Biceps.—Long head ends in a very stout tendon, attached to the head of the fibula as usual. From it, in the upper third of the thigh, a fasciculus extends to the inner lip of the *línea aspera* and internal supracondylar ridge (see figs. 1 and 2). On the left side this fasciculus is 1 cm. broad, and gradually expands to 4 cm., and gets a special attachment to a prominent tubercle on upper part of supracondylar ridge; 4 cm. below its origin it is crossed obliquely by a tendinous intersection, which extends through its whole thickness.

On the right side the fasciculus measures 2 cm., and expands to 11 cm., being inserted into the lower part of inner lip of *línea aspera* and external supracondylar ridge, some fibres passing over on to popliteal surface. The tendinous intersection is rather lower than on the left side.

The *short head*, which measures 15 cm. broad, arises from the lower part of the *línea aspera* to the inner side, and from the popliteal surface of the femur from an oblique line which crosses from within outwards, and which, on the left femur, is raised into a prominent crest at its upper part, and a prominent tubercle at its lower end. The lower edge reaches to a point 4 cm. above the condyles.

Thus the short head of the *Biceps* and *Vastus internus* are in contact with one another for a space of 7 cm. (see figs. 1 and 2).

Gastrocnemius.—Inner head arises by a very strong tendinous expansion attached to the lower end of the internal supracondylar ridge and the popliteal surface of the femur, extending as far as the middle line and as high as the lower border of the short head of the *biceps*. On the right side the attachment to the popliteal space is not quite so extensive, but a special slip arises from the middle of the space, winds to the outer side of the vessels, and ends in a tendon which joins the mesial raphé of the muscle. The outer head arises from the outer side of the external condyle only, and has in its substance a sesamoid cartilage, which facets the outer lip of the condyle.

Plantaris arises from the outer condyle, and slightly from the external supracondylar line, and on the left side from the sesamoid cartilage in the outer head of the *gastrocnemius*.

Popliteus arises partly from the capsule of the joint, chiefly from a strong tendon, which divides like the limbs of a Y, the one going to the external condyle below the external lateral ligament, further back than usual, the second to the tip of the spine of the fibula.

There is nothing special to note as to the muscles of the leg. Neither the *Tibialis anticus* nor *posticus* is bulky out of proportion to the other muscles.

The tendon of the *Posticus* is provided with a specially well-marked groove on the back of the internal malleolus, and the tendon of the *Peroneus longus* plays, as round a pulley, over a very prominent peroneal spine, which projects, like the hook of the unciform, from the outer side of the *os calcis*.

In the foot, the *Flexor brevis digitorum* has but three tendons; that to the little toe springing from a short fusiform belly attached to the tendon of the long flexor.

The *Flexor longus hallucis* tendon divides into two: the one goes to

the hallux, the second divides again into two slips, which pass to the second and third toes, being joined by the corresponding slips of the flexor longus digitorum.

There is no special *Opponens minimi digiti*, but some of the fibres of the Flexor brevis are inserted into the inner side of the shaft of the metacarpal bone.

The tendon of the Peroneus longus has a sesamoid where it plays over the cuboid, and is attached to the 1st metatarsal, and sends a slip to the internal cuneiform.

The tendon of the *Tibialis posticus* sends a very strong slip, attached to the bases of the 2nd, 3rd, and 4th metatarsals, and middle and external cuneiform bones, especially the latter, and this slip is so strong that it appears as the continuation of the tendon, the attachment to the tuberosity of the navicular being merely a lateral expansion from it. There is a sesamoid in the tendon where it plays on the calcaneo-navicular ligament.

Peroneus tertius forms a 5th tendon to the extensor longus digitorum, and is attached to the anterior border of the base of the 4th metatarsal and the fascia of the 4th interosseous space.

I do not purpose to enter into any elaborate analysis of this somewhat formidable series of varieties, but it is very interesting to note the concurrence in one individual of so many variations, which remind one of the descriptions of anthropoid myology. It is also a striking fact that, while the varieties in the upper extremities are largely unilateral, those in the lower extremities are practically symmetrical, especially in the muscles of the thighs, where the departure from the normal European type is most marked.

The remarkable arrangement of the *Adductor magnus* and *Biceps flexor cruris* deserve special notice, because I do not find that they have been described as occurring in the European, and because they have a bearing on the characters of the Femora, which will be described in a special paper.

In the Gorilla and Orang, described by Hepburn,¹ the adductor magnus closely conformed to the corresponding muscle in Man, but in his Chimpanzee and Gibbon it was fasciculated. In the former the ischial head was separate, so as to act as an accessory hamstring muscle, but in the latter it was fused with the rest of the muscle, and its tendon ended on the supracondylar ridge. In the Chimpanzee the pubic portion of the muscle spread out on the popliteal surface of the femur, but in the Gibbon it did not come down so low even as in Man, and the short head of the

¹ *Jour. of Anat. and Phys.*, vol. xvi.

biceps came in contact with the vastus internus. The short head of the biceps also differed from that in the other apes by joining the tendon of the long head.

Thus the arrangement of the two muscles in this Negro very closely corresponded to that present in Hepburn's Gibbon.

The accessory fasciculus of the long head of the biceps was not present in any of Hepburn's specimens, but Church¹ described such a muscle in a Chimpanzee, and Dr Arthur Keith informs me that it was a common feature in his numerous dissections.

I am not aware that such a fasciculus has been described in European myology, although a slip from one or other of the hamstrings may be given to the fascia, as the 'tensor fasciæ suralis.'

The remarkable bilateral symmetry of the varieties in the lower extremities tempts one to look for some relation to function. The facets described by Professors Thomson and Charles were extremely well marked; and whatever be the origin of the variations, the arrangement of the muscles as a whole is such as might suggest its having been pressed into special service in connection with squatting.

The separate fasciculi of the adductor magnus, acting with the brevis, would act as accessory flexors of the hip, while the fourth gluteal would act as a rotator inwards of the flexed femur. The strong femoral head of the biceps would be a powerful short flexor of the knee, while the femoral fasciculus would serve as an accessory extensor of the femur in the assumption of the erect attitude, tending also to tilt the femur outwards, so as to rectify the rotation of the bone which takes place in extreme flexion. The specially strong and extensive insertion of the semi-membranosus would find a similar explanation, and so also the powerful inner head of the gastrocnemius. The tibialis posticus and peroneus longus, acting in concert from the middle line of the foot, and prevented from slipping forwards, the former by its deep groove, the latter by its hook-like peroneal spine, would come into play in extending the ankle on the fixed foot in resuming the upright posture.

¹ Church, *Nat. Hist. Review*, 1862.

ADDITIONAL NOTE ON THE MYOLOGY OF A NATIVE OF DACCA, IN BENGAL.

After the above paper was completed, a subject belonging to another of the dark-skinned races was brought into the dissecting-room. He was an adult male, belonging to the mixed race from the Calcutta coast, familiar as Lascars on board ship. My notes on his myology are mostly negative. With two exceptions, the few varieties noted are unilateral, and of these two only does he share with the Negro. Apart from the question of race, the three principal unilateral varieties noted are of some interest,—viz., the presence of a 'costo-scapular' and a 'sterno-scapular' muscle, and the arrangement of the extensor indicis.

I. *Head and Neck and Back.*

The *sterno-mastoid* on both sides is separated in the greater part of its extent into its three component parts,—sterno-mastoid, cleido-mastoid, and cleido-occipital. All the other muscles are normal except the *Scalenus anticus*, which has one slip less than usual. The muscles of the back conform almost exactly to the text-book description. The *Transversalis colli* has slips from the upper ten dorsal transverse processes.

II. *Trunk and Abdomen.*

Latissimus dorsi has slips from the four lower ribs, and *Serratus magnus* arises from nine ribs on the left, ten on the right side.

Pectoralis major of left side gives off a slip from the lower part of its deep surface, which is attached to the common tendon of origin of the biceps and coraco-brachialis from the coracoid process, forming thus a *Costo-scapular* slip.

Subclavius on the left side is absent, but replaced by a *sterno-scapular* muscle supplied by the nerve to the subclavius. It is attached by a rounded tendon to the 1st costal cartilage, and by fleshy fibres to the superior border of the scapula, extending from the attachment of the posterior belly of the omo-hyoid to the superior angle.

There is no *sternalis*, *dorso-epitrochlearis*, or *aschel-bogen*.

III. *Intrinsic Muscles of Upper Extremity.*

Palmaris is absent on the right, present on the left side.

Extensor carpi ulnaris on both sides has a separate tendinous slip, which springs from a partially separate muscular belly on the right side, and is inserted into the fascia over the base of the 4th metacarpal bone.

Pronator quadratus on the left side is divided into two laminæ, the upper of more oblique fibres is partially attached to the radius, partly to a tendinous band which is attached below to the anterior border of the lower end of that bone; the lower and deeper lamella is composed of transverse fasciculi from ulna to radius.

Extensor indicis on the left side gives off from its ulnar side two small fusiform fleshy bellies, which end on delicate tendons. The first passes under the annular ligament, and over the 2nd interosseous space. Here it again ends in a fleshy belly, which extends the whole length of the interosseous space, and is attached to the base of the 1st phalanx of the middle finger with the 2nd dorsal interosseous muscle. The second tendon also passes under the annular ligament, to end in the fascia over the back of the carpus.

Lumbricals: 4th is rudimentary on both sides; 1st and 2nd arise only from the radial sides of their respective tendons.

IV. Lower Extremity.

There is no *Psoas parvus*.

Plantaris absent on the left, present on the right side; otherwise, all the muscles of thigh and leg are normal.

Flexor brevis digitorum has three tendons only, the perforated tendon of the 5th digit arising from a short fusiform belly attached to the tendon of the long flexor.

Flexor longus hallucis tendon on both sides divides under the internal annular ligament into two: the larger division goes to the hallux; the other divides into three slips, which join the corresponding slips from the long flexor of the toes.

The *Accessorius* is attached to the outer side of the second slip of the flexor longus hallucis, not to the tendon of the flexor longus digitorum.

In the arrangement of the tendons of the long and short flexors of the toes alone, have the two cases any variations in common; but even this is of some interest, from its recognised atavistic character.

The so-called squatting facets were present, but were not more marked than I have seen them, even in European bones; the external condylar surface of the tibia was somewhat flattened; but in both these respects, and in the characters of the astragalus, there was a marked difference from the Negro bones.

LITERATURE.

As my object has been only to record my own dissection, I have not attempted to establish any comparison with others already published, but I append a list of references to the literature of the subject:—

(1) TURNER, Sir W., "Dissection of a Negro," *Jour. Anat.*, xiii. p. 382.

(2) ——— "Dissection of a second Negro," *Jour. Anat.*, xiv. p. 244.

(3) CHUDZINSKI, "Contrib. à l'étude des variations muscul. dans les races humaines," *Revue d'anthrop.*, 1882, pp. 280–308, pp. 613–627. This includes results of two previous memoirs—12 negro dissections.

(4) ——— "Quelques mots sur l'anat. de deux Nègres," *Revue d'anthropol.*, 1884, pp. 603–616.

(5) GIACOMINI, C., "Sopra l'anat. del Negro iv. varieta nel Sistema muscolare," Torino, 1882.

(6) ——— "Annot. Sopra l'anat. del Negro," *Giornale della R. Accad. di Med. di Torino*,—various memoirs from 1884 to 1892; also *Arch. ital. de Biologie*, T. 17, 1892, F. 3, pp. 337–371.

(7) TESTUT, "Contrib. a l'anat. compar. des races Nègres," Bordeaux, 1884: Bellini et Cie.

(8) ——— "Les anomal. muscul. chez les Nègres et chez les Blancs," *Internat. Monatschrift*, B. 1, s. 285, 1884.

(9) MICHEL, "Two cervical muscular anomalies in the Negro," *Med. Record*, New York, 1892, v. 41, pp. 125–128.

REPLIES TO QUESTIONS ISSUED BY THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

By WILLIAM A. J. ALEXANDER, M.A., M.B., C.M., *late Demonstrator of Anatomy, University of Edinburgh.*

THE following replies (four in number) have been drawn up from observations made on 12 bodies (8 females and 4 males) in the dissecting-room of the University of Edinburgh during the summer session of 1895. The numbers 1 to 12 indicate respectively the same 12 bodies throughout. They were prepared for the Committee of Collective Investigation of the Anatomical Society, but through an oversight were omitted from the Report published in this *Journal*, October 1896, page 31.

QUESTION I.

The eighth costal cartilage :

The distance in millimetres at which its extremity is placed from the margin of the sternum.

| | Sex. | Right. | Left. |
|-------|------|---|--------------------|
| No. 1 | F. | 58 mm. | 65 mm. |
| 2 | F. | 65 | 69 |
| 3 | F. | 55 | 57 |
| 4 | M. | 74 | { 7th 42 8th 82 |
| 5 | F. | 52 | 55 |
| 6 | F. | 38 | 36 |
| 7 | M. | 67 | 68 |
| 8 | M. | 68 | 70 |
| 9 | F. | 78 | 65 |
| 10 | F. | 8th unites with xiphoid and last piece of gladiolus just below 7th, 9th, 80 | |
| 11 | M. | 60 | 43 |
| 12 | F. | 59 | 74 67 |

The above table indicates the result of measurements made on the twelve bodies of the distance of the tip of the 8th (and in the case of No. 4 also of the 7th, and in No. 10 also of the 9th) costal cartilage from a point on the corresponding edge of the sternum, determined by passing the knife as far up between the sternum and the lowest sternal rib-cartilage as it would go without cutting into the chondro-sternal joint,—i.e., a point on the corresponding edge of the sternum on a level with the lower end of the last chondro-sternal joint.

QUESTION II.

The relation of the great sciatic nerve to the pyriformis muscle.

| | Sex. | Right. | Left. |
|-------|------|--------|-------|
| No. 1 | F. | N. | N. |
| 2 | F. | N. | N. |
| 3 | F. | N. | S. |
| 4 | M. | N. | S. |
| 5 | F. | S. | N. |
| 6 | F. | S. | N. |
| 7 | M. | N. | N. |
| 8 | M. | N. | N. |
| 9 | F. | S. | N. |
| 10 | F. | N. | N. |
| 11 | M. | N. | N. |
| 12 | F. | N. | N. |

In the above table, which gives the result of the examination of 12 bodies,—

N. indicates that the relation was *normal*,—i.e., that the nerve emerged from the pelvis in one trunk wholly below the pyriformis muscle.

S. indicates that the nerve was *split* into two trunks, the upper of which pierced the pyriformis muscle in leaving the pelvis, the lower emerging wholly below the pyriformis.

QUESTION IV.

The arrangement and number (if possible) of the lymphatic glands accompanying the common and external iliac arteries.

I examined 9 out of the 12 bodies.

In all of these the glands were found in fairly close relation to the arteries, lying chiefly to the outside or inside of the vessel. A few, however, lay partly in front of the artery, and one or two partly behind. The large and medium-sized glands lay for the most part in linear series, roughly parallel with the vessel; but in those cases in which, instead of one or two large glands, there appeared a group of smaller glands, these often departed from the linear order, and were disposed in more or less irregular clumps. In Nos. 1, 3, 4, 6, 9, and 11, a very large gland was observed lying external to the left common iliac artery, or a little higher, to the left of the lower end of the abdominal aorta. It was more or less oval in shape, and in one case bifurcated, with two long processes directed upwards. A deep epigastric gland was found at distal end of external iliac artery in all the bodies examined, except in No. 6 (where it was absent on both sides), Nos. 3 and 11 (absent on left side), but in all these three it had probably been removed before observations were made.

The following table indicates the number of glands observed, and

their relation (external or internal) to common and external iliac arteries. In some cases, especially in body No. 6, but also to some extent in Nos. 3, 5, and 11, some glands may have been removed by dissectors before I could make observations, especially those towards distal end of external iliac artery.

| No. 1 F. | | | No. 3 F. | | | No. 4 M. | | | | | |
|-----------|------|-----------|-----------|----|-----------|-----------|---|-----------|------|---|---|
| External. | | Internal. | External. | | Internal. | External. | | Internal. | | | |
| R. | C.I. | 4 | 1 | R. | C.I. | 6 | 0 | R. | C.I. | 4 | 2 |
| | E.I. | 2 | 3 | | E.I. | 1 | 1 | | E.I. | 3 | 2 |
| L. | C.I. | 3 | 2 | L. | C.I. | 2 | 3 | L. | C.I. | 5 | 2 |
| | E.I. | 0 | 1 | | E.I. | 1 | 2 | | E.I. | 3 | 6 |
| Total, | | 16 | Total, | | 16 | Total, | | 27 | | | |

| No. 5 F. | | | No. 6 F. | | | No. 9 F. | | | | | |
|-----------|------|-----------|-----------|----|-----------|-----------|---|-----------|------|---|---|
| External. | | Internal. | External. | | Internal. | External. | | Internal. | | | |
| R. | C.I. | 5 | 0 | R. | C.I. | 2 | 1 | R. | C.I. | 2 | 1 |
| | E.I. | 2 | 0 | | E.I. | 3 | 0 | | E.I. | 3 | 2 |
| L. | C.I. | 2 | 0 | L. | C.I. | 3 | 0 | L. | C.I. | 5 | 3 |
| | E.I. | 2 | 4 | | E.I. | 1 | 0 | | E.I. | 1 | 2 |
| Total, | | 15 | Total, | | 10 | Total, | | 19 | | | |

| No. 10 F. | | | No. 11 M. | | | No. 12 F. | | | | | |
|-----------|------|-----------|-----------|----|-----------|-----------|---|-----------|------|---|---|
| External. | | Internal. | External. | | Internal. | External. | | Internal. | | | |
| R. | C.I. | 8 | 0 | R. | C.I. | 3 | 2 | R. | C.I. | 3 | 1 |
| | E.I. | 2 | 11 | | E.I. | 2 | 2 | | E.I. | 3 | 1 |
| L. | C.I. | 4 | 1 | L. | C.I. | 4 | 1 | L. | C.I. | 2 | 1 |
| | E.I. | 3 | 6 | | E.I. | 5 | 0 | | E.I. | 1 | 4 |
| Total, | | 35 | Total, | | 19 | Total, | | 16 | | | |

In No. 10 the glands were mostly small, and disposed in groups.

QUESTION V.

The mode of origin of the branches of the internal iliac artery.

I examined 11 out of the 12 bodies, and made sketches, on which the following tables are based.

The initial letters A.D. signify anterior division, P.D. posterior division, and I.I. the trunk of the internal iliac artery.

| No. | Sex. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|--|------|---------------------------|-------------------|-------------------|--------------------------------|--------------------------|------------------|-----------------------|-------------------|-------------------|-----|-------------------|-------------------|
| Ilio-lumbar, | R. | A.D. along with Sc. | I.I. | P.D. | P.D. | P.D. | P.D. | P.D. | I.I. | P.D. and I.I. | ... | I.I. | P.D. and I.I. |
| | L. | P.D. | I.I. | ... | I.I. at bifurc. | P.D. | P.D. | P.D. | P.D. and C.I. | P.D. | ... | P.D. | I.I. |
| Lateral Sacral, | R. | P.D. | I.I. | P.D. | P.D. | P.D. | P.D. | P.D. | I.I. and A.D. | P.D. | ... | P.D. | I.I. |
| | L. | P.D. | I.I. | ... | P.D. | P.D. | P.D. | P.D. | P.D. with Ob. | P.D. | ... | P.D. | I.I. |
| Gluteal, | R. | P.D. | I.I. with M.H. | P.D. | P.D. | P.D. with Ob. | P.D. | P.D. | I.I. | P.D. | ... | P.D. | I.I. with I.L. |
| | L. | P.D. | I.I. | ... | P.D. | P.D. with Ob. and Sc. | P.D. with Sc. | P.D. | P.D. | P.D. | ... | P.D. | I.I. |
| Obliterated Hyp. or Hypogastric Trunk, | R. | A.D. | A.D. | A.D. | I.I. at bifurc. with Ob. | A.D. | I.I. | A.D. | A.D. | A.D. | ... | A.D. | A.D. |
| | L. | A.D. | A.D.! | ... | A.D. | A.D. | A.D. | A.D. | A.D. | A.D. | ... | A.D. | I.I. |
| Sciatic, | R. | A.D. with I.L. | A.D. with I.P. | A.D. with I.P. | A.D. with I.P. | A.D. with I.P. | A.D. with Ob. | A.D. with I.P. | A.D. with S.V. | A.D. with I.P. | ... | A.D. with I.P. | A.D. with I.P. |
| | L. | A.D. with I.P. | A.D. with I.P. | ... | A.D. with I.P. | P.D. with Ob. | P.D. with Gl. | A.D. with Ob. + | A.D. with I.P. | A.D. with I.P. | ... | A.D. with I.P. | I.I. |

| | | | | | | | | | | | | | |
|---------------------------------------|----|----------------|---------------|---------------|-----------------|------------------------|-----------------------------|-----------------|------------------------|-------|---------------|---------------|-----------------------------|
| Internal Pudic, . | R. | A.D. with Ob. | A.D. with Sc. | A.D. with Sc. | A.D. with Sc. | I.I. with H.Tr. and V. | A.D. with Sc. | A.D. | A.D. with Sc. | ... | A.D. with Sc. | A.D. with Sc. | A.D. with Sc. |
| | L. | A.D. with Sc. | A.D. with Sc. | ... | A.D. with Sc. | A.D. with H.Tr. | A.D. with Sc. | A.D. | A.D. with Sc. | ... | A.D. with Sc. | A.D. with Sc. | I.I. with H.Tr. |
| Obturator, . | R. | A.D. with I.P. | E.I. | ... | I.I. with H.Tr. | P.D. with Gl. | A.D. with Sc. | A.D. with H.Tr. | A.D. with L. | ... | ... | ... | ... |
| | L. | A.D. with | E.I. | ... | A.D. | P.D. with Sc. | A.D. | A.D. | A.D. with H.Tr. and I. | ... | ... | ... | I.I. |
| Uterine, . | R. | ... | ... | ... | ... | ... | I.I. with H.Tr. | ... | ... | ... | ... | ... | A.D. with Sc. and I.P. I.I. |
| | L. | ... | ... | ... | ... | ... | A.D. with I.P. | ... | ... | ... | ... | ... | A.D. |
| Inferior Vesical, . | R. | ... | ... | ... | ... | ... | I.I. with Hyp. Tr. and I.P. | A.D. | A.D. | ... | ... | ... | A.D. |
| | L. | ... | ... | ... | ... | ... | ... | A.D. | A.D. | ... | ... | ... | ... |
| Middle Vesical or Superior Vesical, . | R. | H.Tr. | H.Tr. | H.Tr. | H.Tr. | H.Tr. | H.Tr. | H.Tr. | H.Tr. | H.Tr. | H.Tr. | H.Tr. | H.Tr. |
| | L. | H.Tr. | H.Tr. | ... | A.D. | H.Tr. | H.Tr. | H.Tr. | H.Tr. | ... | H.Tr. | H.Tr. | ... |

Middle Hemorrhoidal, in the few cases in which it could be traced, was found arising normally from A.D. In one doubtful case (No 2 R.) the branch marked M.H. arising from gluteal is probably a lateral sacral.
 The distribution of the internal iliac artery (I.I.) into an anterior division (A.D.) with 3 visceral and 3 parietal branches, and a posterior division (P.D.) with 3 parietal branches, being taken as normal, deviations from the normal have been shown in the above table in *Italics*.
 W. A. J. A.

NOTES ON THE DISSECTION OF A THIRD NEGRO.

By Prof. Sir WM. TURNER, F.R.S.

IN volumes xiii. and xiv. of this *Journal* I recorded some variations in the arrangements of structures observed during the dissection of two Negro subjects. Subsequently, in 1881–82, I had the opportunity of examining a third Negro in the course of dissection by several of my students. I entrusted the charge of the dissections to Dr George Mackay, from whose memoranda on the variations which were observed the following notes are compiled.

MUSCULAR SYSTEM.—The *Platysma myoides* was remarkably well developed. A *Rectus thoracis* was situated on each side as a triangular thin muscle in relation to the sternal ends of the upper ribs and intercostal muscles. It arose from the upper border of the third rib for about two inches external to its costal cartilage and from the anterior intercostal membrane of the second space. The fibres ascended superficial to the second rib, to be inserted into a rough tubercle on the upper surface of the first rib, immediately anterior to the groove for the subclavian vein. I have figured in this *Journal*, vol. ii. p. 393, an example of this muscle in a European, which extended from the fifth to the first rib.

In the left upper limb the *Flexor sublimis digitorum* had no radial origin. Close to its condylar origin there arose a muscular slip, which united with the tendon of the Flexor profundus digitorum which ended in the medius finger. Another slender muscular slip was inserted into the Flexor longus pollicis muscle about its middle, by a distinct tendon. That portion of the Flexor sublimis digitorum going to the index finger arose under cover of the rest of the muscle from the internal condyle of the Humerus, and also from the inner aspect of the coronoid process of the ulna internal to the ulnar origin of the Pronator teres. The muscular fibres formed a short thick fleshy belly, but at a distance of $2\frac{1}{2}$ inches from their origin they converged to a strong tendon about 2 inches in length. This again gave place to a fleshy belly, which extended nearly to the level of the lower end of the radius. Here it was joined by a delicate muscular slip from the main belly of the Flexor sublimis digitorum, and then terminated in a tendon which remained normal to its insertion into the palmar surface of the index finger. A slender muscle arose from the anterior aspect of the shaft of the radius about its middle, and joined the tendon of the Flexor profundus digitorum which passed to the index finger.

The tendon of the *Extensor carpi radialis longior* gave off a tendinous slip about two inches above the lower end of the Radius,

which passed downwards and inwards to join the tendon of the Extensor carpi radialis brevior at the level of the radio-carpal articulation.

A similar slip from the *Extensor carpi radialis brevior* passed downwards and outwards superficial to the former slip, and joined the tendon of the Extensor carpi radialis longior just at its insertion into the base of the second metacarpal bone.

In each lower limb an extra slip of origin for the *Semitendinosus* muscle, about the size of a small omo-hyoid, arose for about $\frac{1}{3}$ of an inch from the anterior end of the ridge on the inner surface of the Tuber ischii, and became united with the fleshy belly of the semitendinosus just at the upper part of the tendinous intersection.

The *Adductor magnus* muscle consisted of two distinct layers, the lower and larger overlapping the higher and smaller, as seen from behind. This was most distinctly marked on the left side of the body.

In the right *Popliteal space*, several muscular fibres arose from the inner part of the posterior surface of the lower end of the femur, and also from the line leading to the internal condyle for about $\frac{3}{4}$ inch; these formed a fleshy belly (about the size of that of the Plantaris), and after a course of about two inches, blended with the Inner head of the Gastrocnemius.

The *Peroneus tertius* muscle was present in the left leg, but entirely absent on the right side.

In the soles of both feet the *Flexor brevis digitorum* supplied no tendon to the little toe. Its place was taken by a slender muscle which arose from the side of the *Flexor longus digitorum*, as it crossed the flexor longus hallucis. It passed outwards to the base of the little toe, and had an insertion resembling that of the tendon of the flexor brevis digitorum.

A well marked *Abductor ossis metatarsi quinti* was present in both feet.

The *Cricoid cartilage* was unusually large. Its vertical diameter was almost the same at the sides as behind, but in front this diameter was normal, so that the cartilage had the appearance of a deep notch anteriorly.

VESSELS.—The right *subclavian* artery arose as the last branch of the arch, and passed obliquely upwards between the œsophagus and the dorsal vertebræ, to reach the root of the neck of the right side. This variety occurs in Europeans, and has been estimated by Quain and myself at about 4 per 1000 bodies.

The *Femoral vein* lay to the inner side of the artery in its entire course, but in the Hunterian canal another vein, which joined the femoral at the lower border of the pectineus, was situated behind the artery.

The *Peroneal artery* in the right leg did not give origin to its perforating anterior branch: in this limb the peroneus tertius was absent.

NERVES.—The *phrenic* was joined by an accessory branch from the 5th cervical about 1 inch above the insertion of the scalenus anticus into the first rib: also by a branch from the nerve to the subclavius.

The right *Great sciatic* gave off a large branch in the gluteal region, which passed under cover of the gemellus inferior to enter the long head of the biceps immediately after that muscle left the semitendinosus. When under cover of the conjoined tendon of biceps and semitendinosus, another branch arose which gave a twig to the upper part of the adductor magnus, then gave branches to the semitendinosus and semimembranosus, and ended in the lower part of the adductor magnus. The nerve to the short head of the biceps arose from the great sciatic opposite the lower border of the gluteus maximus, and ended by giving two articular branches to the knee, one of which pierced the posterior ligament, whilst the other ran close to the external superior articular artery.

In the right limb both the *communicating nerves* arose from the internal popliteal: in the left limb they arose normally, but passed to their distribution without uniting, though a delicate connecting twig passed between them.

The branch of the *obturator nerve* to the subsartorial plexus pierced the pectineus muscle before it joined the twigs from the internal cutaneous and long saphenous.

MESENTERY.—The rectum had two mesenteries, one of which was the normal. The other was a double fold of peritoneum which passed from the antero-lateral aspect of the rectum to about the middle of the left ilio-pectineal line, where it blended with the parietal peritoneum. The upper border of this fold was free and concave. Between it and the proper meso-rectum was a funnel-shaped pouch, about $2\frac{1}{2}$ inches in depth, the opening into which was in an oblique plane directed downwards and outwards.

"AN EXPERIMENTAL RESEARCH UPON CEREBRO-CORTICAL AFFERENT AND EFFERENT TRACTS." By DAVID FERRIER, M.D., F.R.S., *Professor of Neuropathology*, and WILLIAM ALDREN TURNER, M.D., F.R.C.P., *Demonstrator of Neuropathology, King's College, London*.¹ (Communication made to the Royal Society of London, June 17, 1897.)

(Abstract.)

THE primary object of the research has been to elucidate by the aid of destructive lesions, and the study of the consecutive degenerations, the tracts by which impressions of general and special sensibility are conveyed to the cortex of the brain. For this purpose, the cortical area, supposed to be the sensory centre under consideration, was extirpated; and, secondly, the nerve, tract or primary ganglionic structure connected therewith was divided or destroyed.

In this way strands of degeneration were induced, in due course, of cortical afferent or efferent nature, revealed by the osmium-bichromate method of Marchi.

The systems upon which experiments have been performed were:—

- (a) The cerebral portion of the *visual system*, consisting of removal of the occipital lobe, extirpation of the angular gyrus, destruction of the pulvinar thalami, and division of the splenium corporis callosi.

The degenerations showed that this portion of the visual system was composed of a corticofugal tract, passing from the occipital lobe, by way of the optic radiations, to the pulvinar thalami of the same side, and to the anterior quadrigeminal bodies, of the same and partly of the other side. The angular gyrus has no descending or efferent tract to the basal ganglia, but is connected by means of association fibres with the superior temporal gyrus, the superior parietal lobule, and the occipital lobe. A system of corticopetal fibres was traced from the optic thalamus to the angular gyrus and the occipital lobe, in which lobe their distribution was as well marked in the external convolutions as in the cuneus and lips of the calcarine fissure.

The angular gyri and occipital lobes are commissurally connected through the splenium and forceps corporis callosi; the callosal fibres having the same cortical distribution as the thalamic fibres.

In this respect our observations are in harmony with those of von Monakow and Vialet.

¹ From the Neuropathological Laboratory, King's College, London.

- (b) The experiments upon the *auditory system* consisted of section of the eighth nerve distal, as well as proximal to, the accessory auditory ganglion; destruction of the posterior quadrigeminal body, and the internal geniculate ganglion, and extirpation of the superior temporal gyrus.

Inasmuch as the experiments necessitated division of the pedunculus flocculi, the degenerations consequent thereon were first eliminated. These were traced into Deiters' nucleus, the vermis cerebelli, and tegmentum pontis, corresponding with the observations of Bruce and Stscherbach by the myelination method.

The direct connexions of the *vestibular* division, as shown by section of the eighth nerve trunk distal to the auditory ganglion, are with Deiters' nucleus and the tegmentum; while there is also a probable direct connexion with the nucleus of the sixth nerve.

The connexions of the *cochlear* division, forming the central auditory tract, were found to pass from the accessory auditory ganglion by way of the corpus trapezoides, in association with the lateral fillet, to the internal geniculate body of the opposite side. Thence a tract was found to ascend to the superior temporal gyrus. This forms the corticopetal or cerebral auditory tract. Degeneration was also traced after destruction of the auditory ganglion into both superior olives, and posterior quadrigeminal tubercles, chiefly of the opposite side. These results are compared with those of Flechsig, Kölliker, etc., obtained by other methods of investigation.

After destruction of the superior temporal gyrus a tract of degeneration was found to descend to the upper part of the pons Varolii, through the outer fifth of the pes cruris. This constitutes the temporo-pontine tract of Bechterew and Déjérine.

The superior temporal gyri are commissurally connected through the forceps of the corpus callosum, and by means of association fibres with the angular gyrus and occipital lobe.

- (c) The *cutaneous sensory* and other *corticopetal systems* were studied by the aid of destructive lesions of the tegment of the pons Varolii, crus cerebri, optic thalamus, the posterior quadrigeminal body and adjacent tegment. Those which specially caused cutaneous anæsthesia were lesions involving the reticular formation of the tegment of the pons and crus.

In some of these cases there was no obvious loss of cutaneous sensibility, while in others this was pronounced. In both cases, however, corticopetal degenerations were induced. These were traced through both limbs of the internal capsule, the external capsule, and the centrum ovale to the cerebral cortex, both on the convexity and mesial aspect, including the gyrus fornicatus. This corticopetal system is less extensive in the frontal than in the other regions of the cerebrum. It would seem to harmonise with the thalamic corticopetal fibres, which Flechsig has recently described as the first, second, and third "sensory" systems, ascending respectively to the Rolandic area, the falciform lobe, the frontal region and gyrus fornicatus, myelinating at different periods.

Many of these fibres of the tegmentum appear to pass through the optic thalamus without ending in it, while others terminate in this ganglion. This is shown by the fact that destruction of the lateral and ventral parts of the optic thalamus led to a more extensive degeneration than that following destruction of the tegmentum alone, the fibres degenerating towards the same cortical regions. But we have not been able to distinguish, by the degenerative method, between those of sensation proper and the other afferent fibres which ascend to the cortex in this region.

Many fibres from the optic thalamus were found to cross by the corpus callosum to the opposite cerebral hemisphere, thus supporting the view of Hamilton that this structure is a decussation as well as a commissure. Our observations show that the decussation is of thalamic corticopetal fibres.

- (d) The other *afferent cranial nerves*, which were made the subject of experiment, were the sensory division of the trigeminus, and the glossopharyngeus, which were divided proximal to their ganglia.

Apart from degeneration of the so-called ascending trigeminal and glossopharyngeal roots, traceable as far as the spinal-medullary junction, no evidence was obtained as to their central continuation.

But the symptoms following lesion of the tegmentum cruris placed the sensory fibres from the face in association with those from the body and limbs.

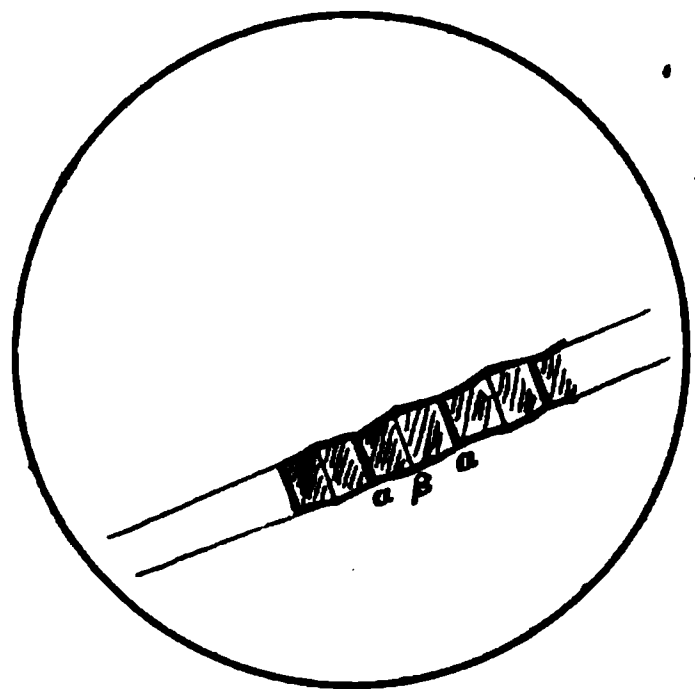
- (e) The experiments upon the *prefrontal* and *frontal* areas confirmed the existence of a fronto-pontine tract, which descends through the anterior limb of the internal capsule and the inner portion of the pes cruris to the pons Varolli.

The subjects of experiment were exclusively monkeys.

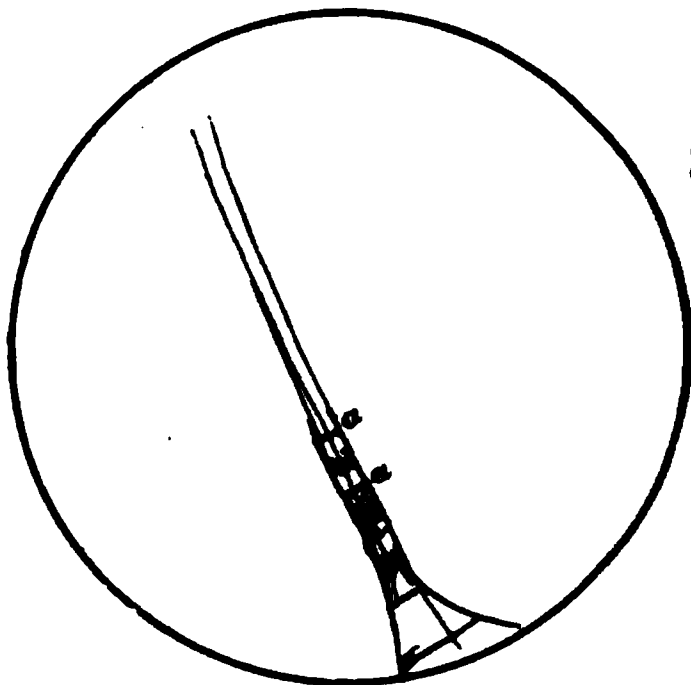
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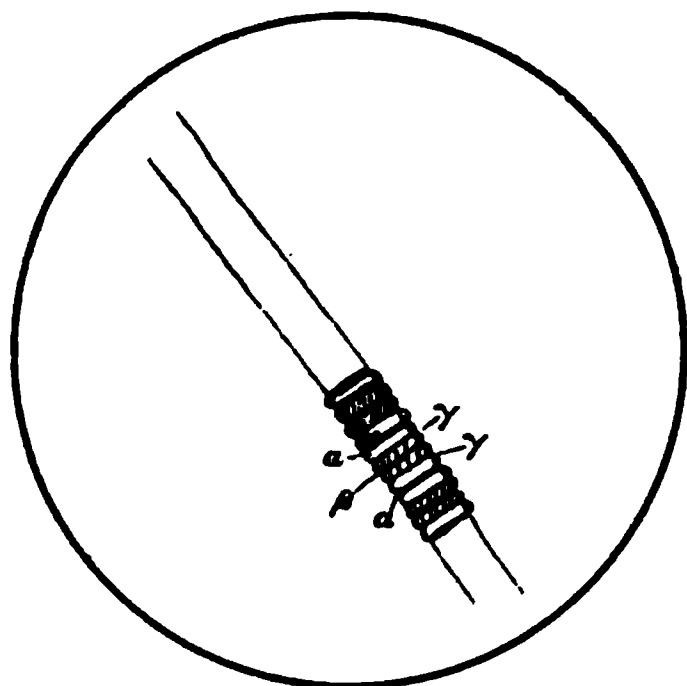
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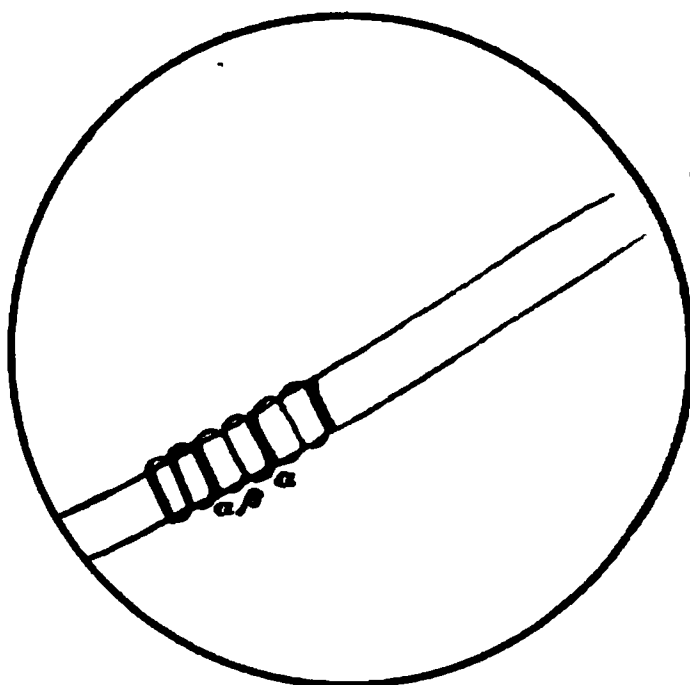
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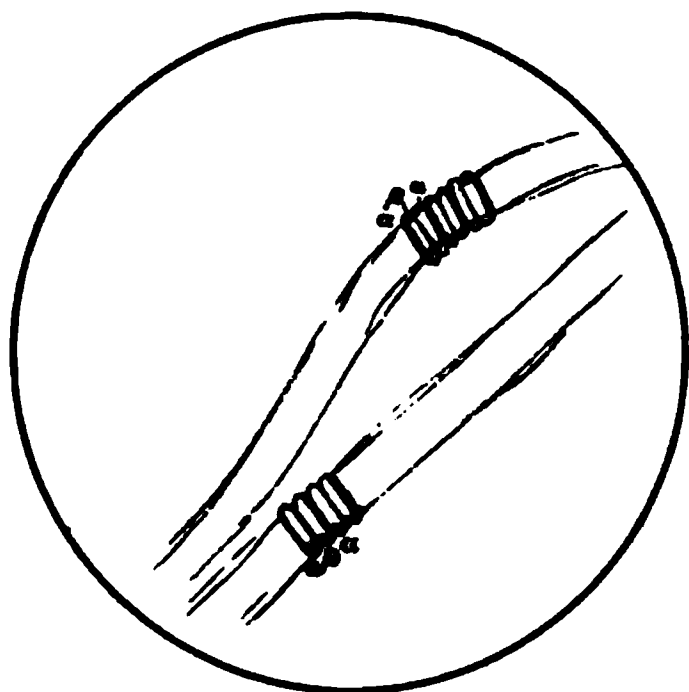
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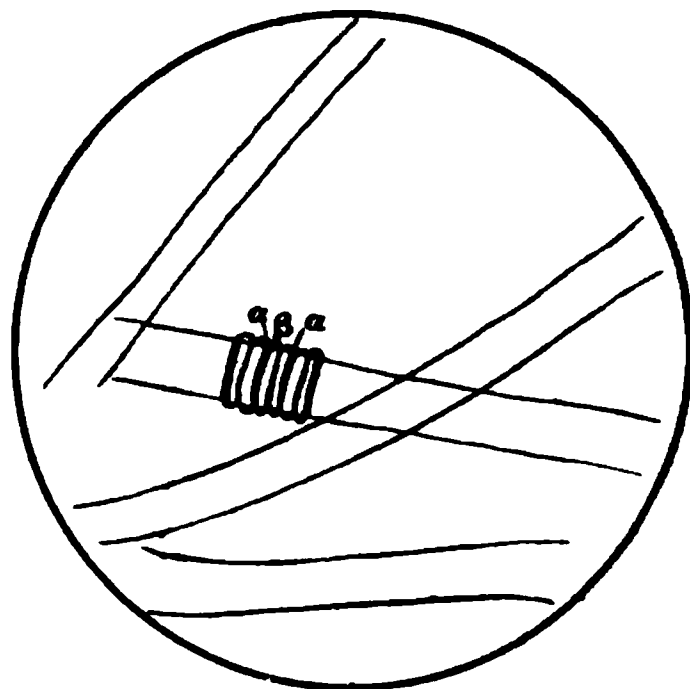
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PLATE XVI.

PHOTO 1. Part of a sarcoistyle teased out from the wing-muscles of the common house-fly and still living in a normal saline solution. The sarcomeres are in a fully extended state (Stage A). The α and β discs are seen as dark transverse lines, bordered by bright lines. The latter are more marked on the right hand side of the discs, probably owing to the fact that the fibril lies slightly obliquely to the plane of the focus. The longitudinal striae are very faintly indicated.

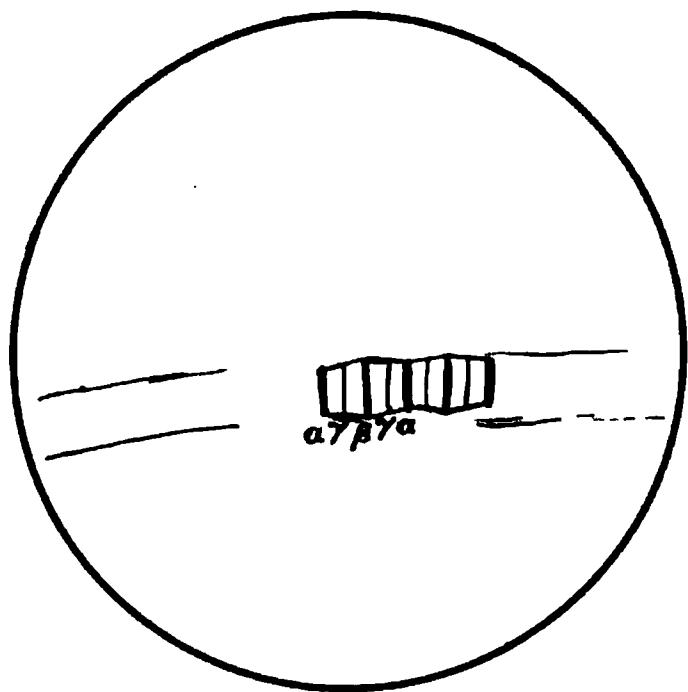
PHOTO 3. Part of a sarcoistyle from the wing-muscles of the water-beetle, fixed by steam in stage B and stained with logwood. All the discs are stained. Each sarcomere is constricted equally by the three elastic discs

PHOTO 5. Part of a sarcoistyle fixed by steam in stage C and stained with logwood. In each sarcomere the β disc constricts the wall deeply. The γ discs are not seen and cause no constrictions. The staining of the wall is well

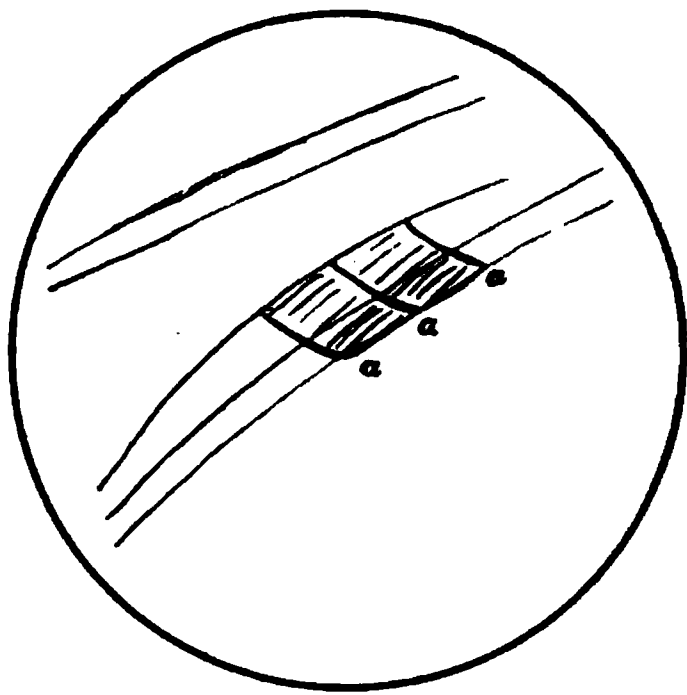
PHOTO 2. Part of one of the exceptionally small sarcoistyles which are occasionally found in teased preparations of the wing-muscles of the common house-fly. It was fixed in stage A by steam and stained with logwood. It shows the staining of the wall and its wrinkled character very well. At the end it has been torn during teasing and appears as a flat wrinkled membrane.

PHOTO 4. Part of a sarcoistyle fixed with steam in a partially contracted state and stained with logwood. Its state is an unusual one. It was chosen because it shows so unmistakably the constrictions produced by the β discs and the stained wall.

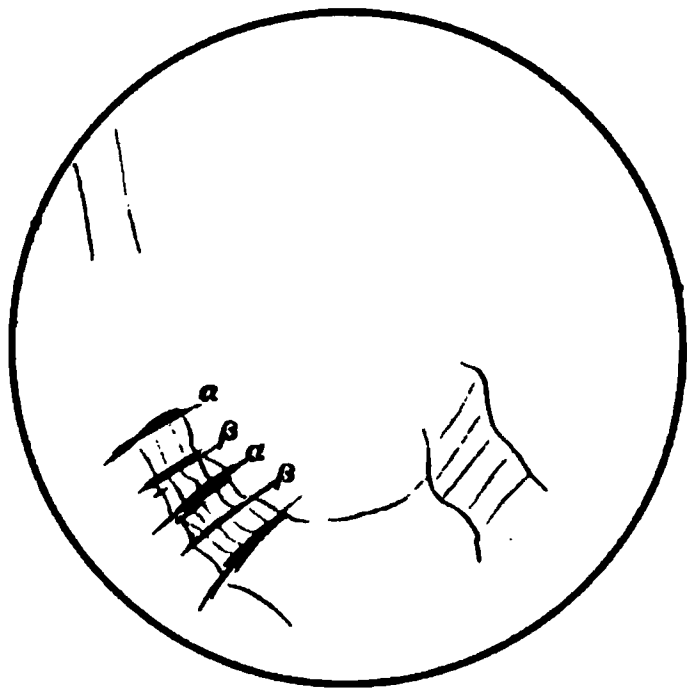
PHOTO 6. Part of a sarcoistyle from the wing-muscles of the water-beetle fixed by steam in a late C stage and stained with logwood. The outline of the wall constricted by the β



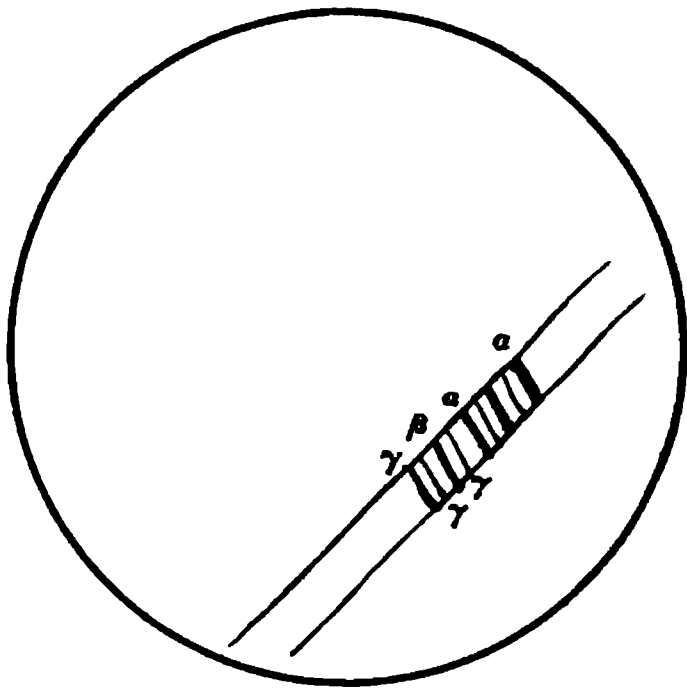
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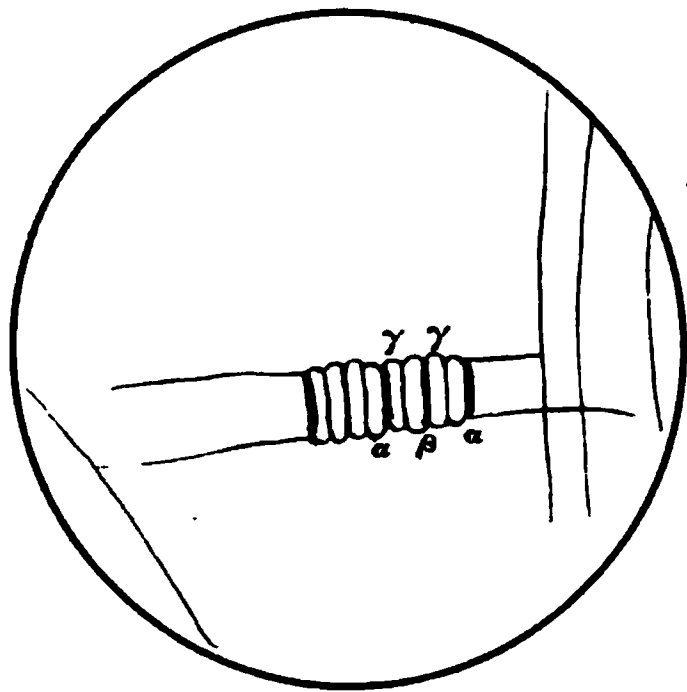
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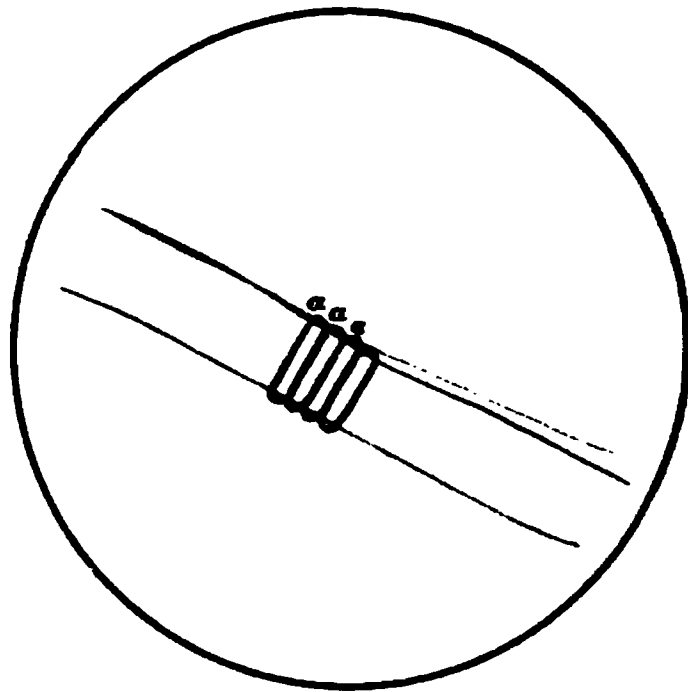
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PLATE XVII.

PHOTO 7. Part of a sarcofile from the wing-muscles of the common house-fly fixed in stage A by steam and stained with logwood. The discs α , β , γ , in each sarcomere are all stained, and under the microscope could be focussed in all planes in the thickness of the fibril. The walls are very little stained.

PHOTO 9. Part of a sarcofile burst by boiling. In the part on the left it seems to have been burst along two sides, and in the part on the right along the under side only.

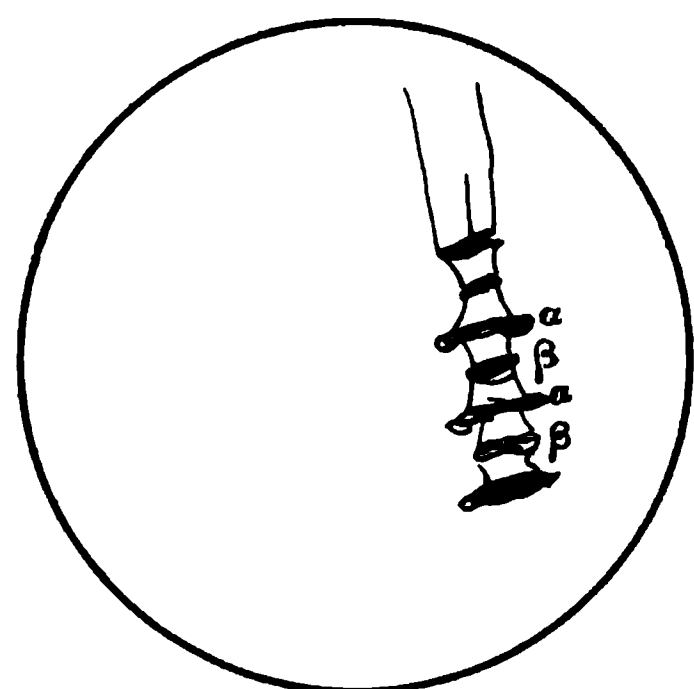
PHOTO 11. Another part of the same sarcofile, in which the sarcomeres are very slightly contracted. The outline of the walls, with the constrictions caused by the γ discs, can be clearly seen.

PHOTO 8. Part of a sarcofile fixed in stage A and stained by logwood, which during teasing has been torn open along one edge. Part of the wall is spread out flat in one plane, but part of the wall of the under side remains in that position, causing the darker appearance of the right hand part.

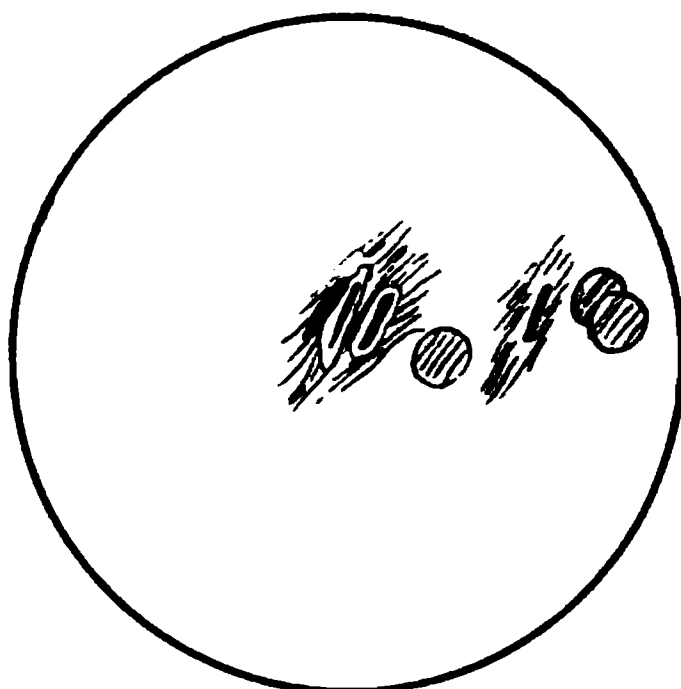
PHOTO 10. Part of a sarcofile from the wing-muscles of the common house-fly fixed by steam and stained with logwood in stage A. All the discs are stained, and the wall is very little stained. The β discs are as thick and as well marked as the α discs and are indistinguishable from them. The γ discs are well stained.

PHOTO 12. Part of sarcofile fixed by steam in stage D and stained with logwood. The discs and the wall are well stained. The outline of each sarcomere is a single flattened curve.

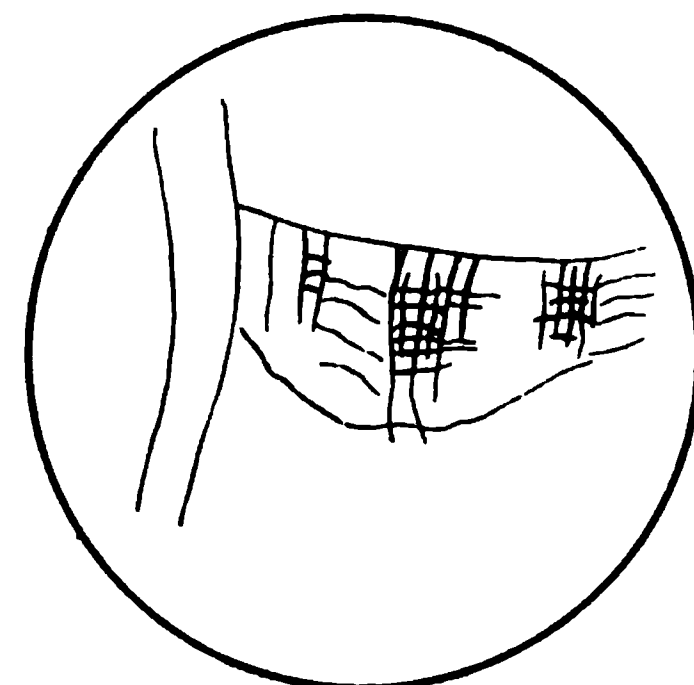




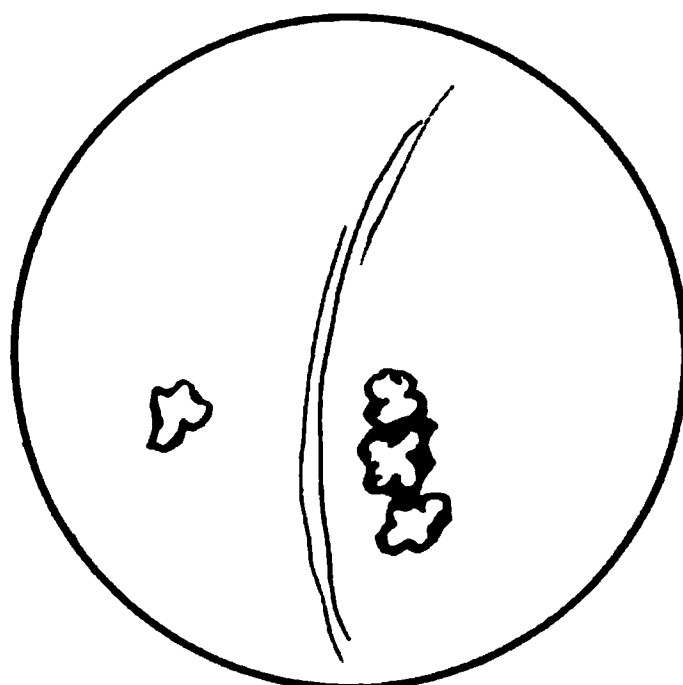
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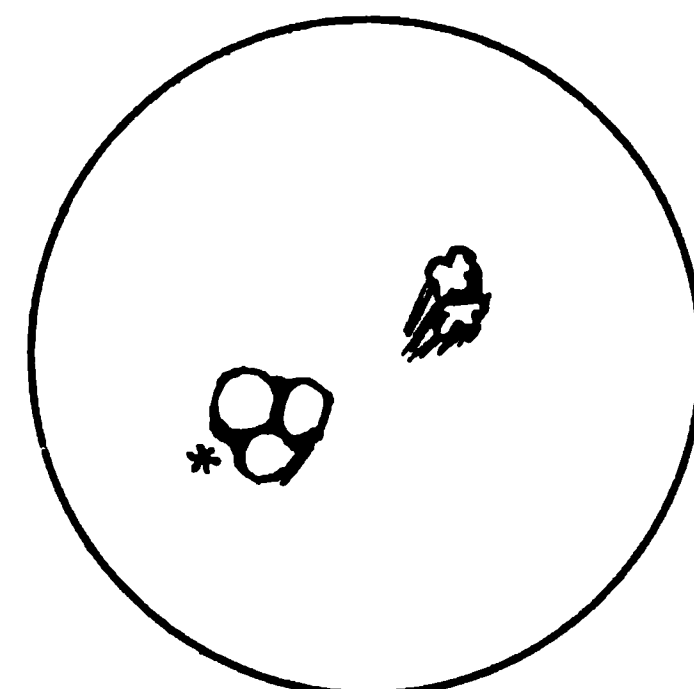
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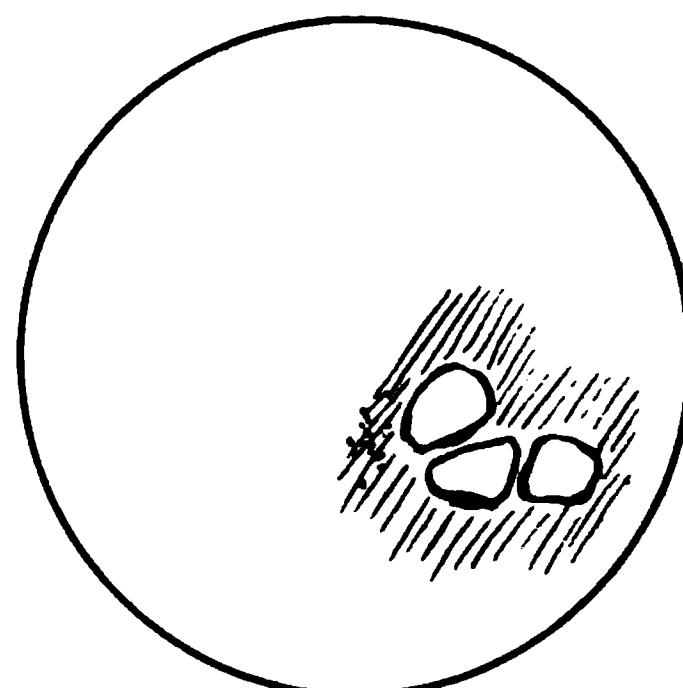
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PLATE XVIII.

PHOTO 13. A torn fibril, from the chambers of which the contents seem to have escaped, leaving the wall partially supported by the α and β discs.

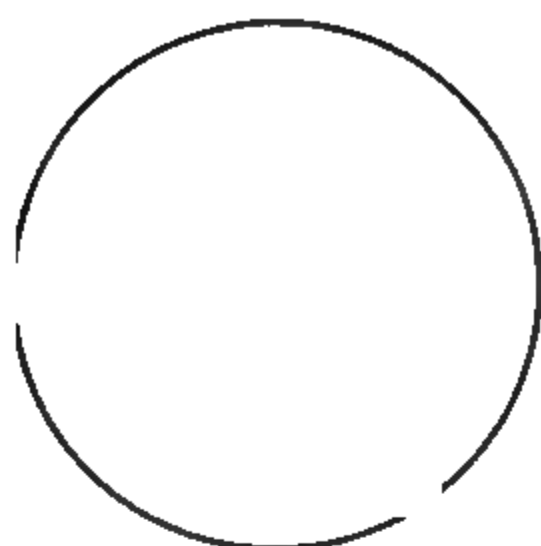
PHOTO 15. Part of a sarcostyle which has been burst along one edge and so that its wall is spread out in one plane. This probably occurred when it was in a contracted state, and it seems to have been drawn out somewhat since the boiling. The remains of the discs express themselves as dark lines across the crinkled membrane.

PHOTO 17. Same as 18, except that at * the fibrils are partially contracted and therefore their sections are of greater diameter and less indented.

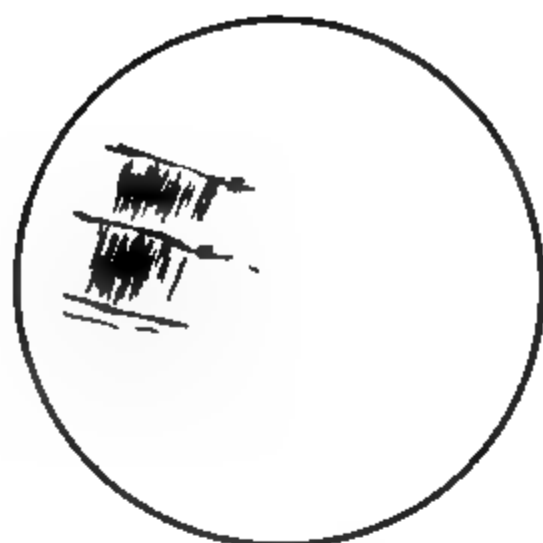
PHOTO 14. Isolated α discs stained with logwood. Some lie flat in the plane of the focus, some are seen on edge and are surrounded by refraction halos.

PHOTO 16. A transverse section of the water-beetle's wing-muscle in a fully extended state, fixed by steam and stained with logwood. Most of the clear areas, which are the sections of the sarcomeres, have deeply indented outlines corresponding to the longitudinal folds of the wall shown in Photo 2.

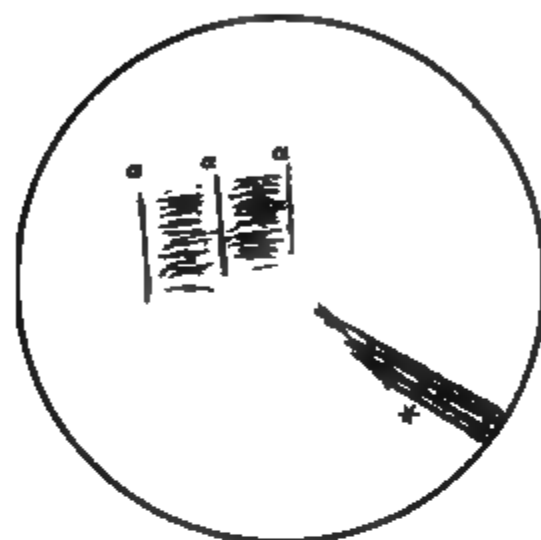
PHOTO 18. Transverse section of contracted wing-muscle of the cockchafer fixed with steam and stained with logwood. The walls of the fibrils are in places more darkly stained than the sarcoplasm.



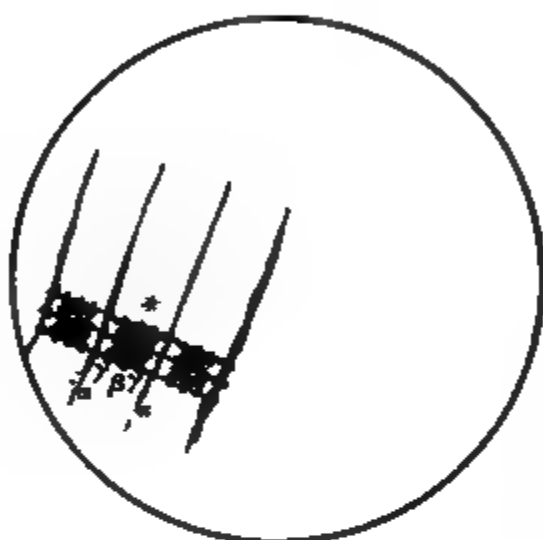
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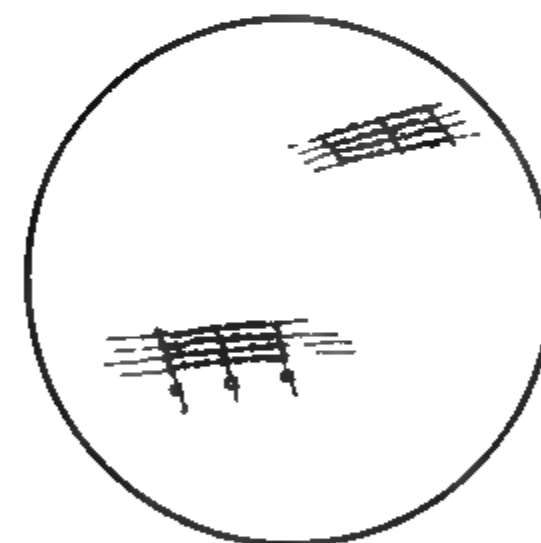
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PLATE XIX.

PHOTO 19. Optical longitudinal section of the fibres of the leg muscles of the water-bettle, of exceptionally coarse structure. It is fixed by steam in a fully extended state, stage A. It is characteristic of these coarser fibres that the larger granules of the sarcoplasm lie about the levels of the α septa, which are secured by them in most parts of the photograph.

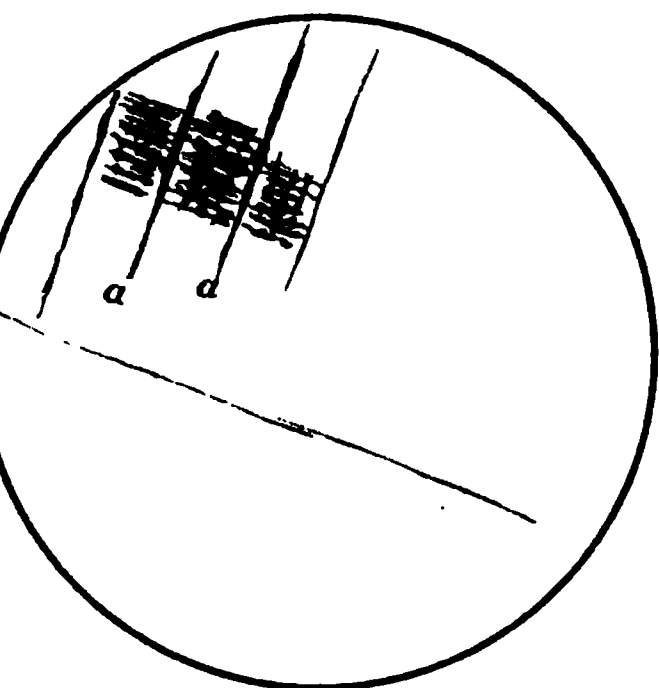
PHOTO 21. Several partially isolated sarcostyles in stage A lying flat in plane of focus. α * the edges of three are seen still in position.

PHOTO 23. Longitudinal section of fibre in stage B (chromic ac. and logwood).

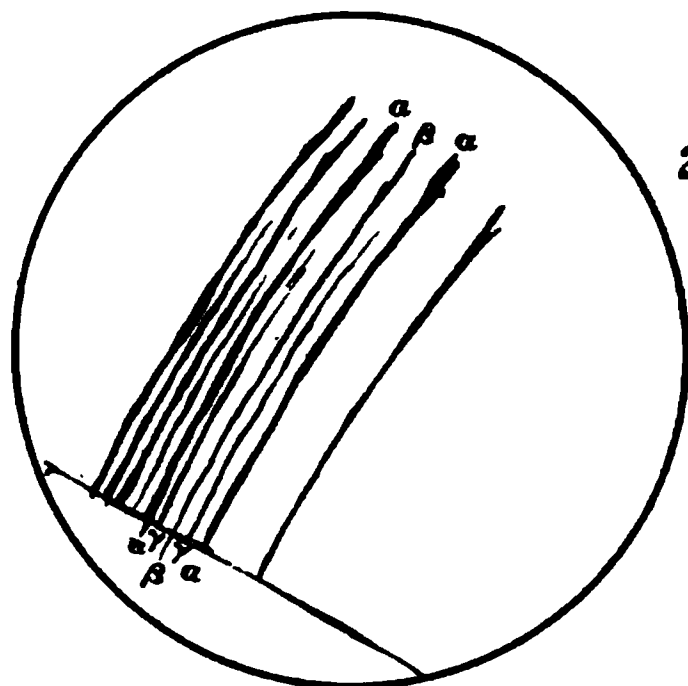
PHOTO 20. Surface view of the narrow ends of a bundle of muscle columns in stage A (chromic and formic mixture and logwood). On the left, one of the columns is spread out in the plane of the focus. The halos of the septa are well shown.

PHOTO 22. Optical longitudinal section of steamed fibre in stage B. The three constrictions in each sarcomere and the corresponding diamond shaped dots of sarcoplasm are shown at α , also the septa optically fused into transverse lines thickened by the dots of sarcoplasm between the sarcostyles.

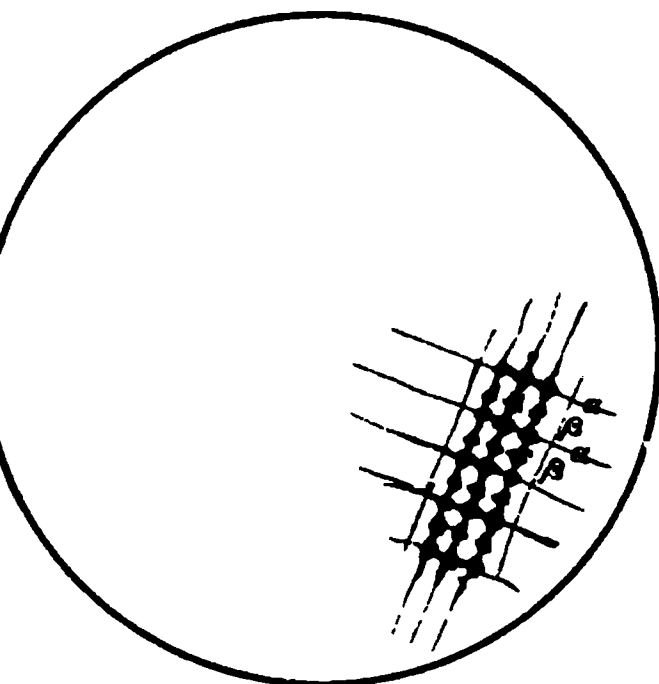
PHOTO 24. Part of an isolated sarcostyle in stage B (chromic acid and logwood). Shows darkly stained α discs and their halos, and dark transverse lines at β which may be due to the discs being stained. The wall of each sarcomere is longitudinally wrinkled.



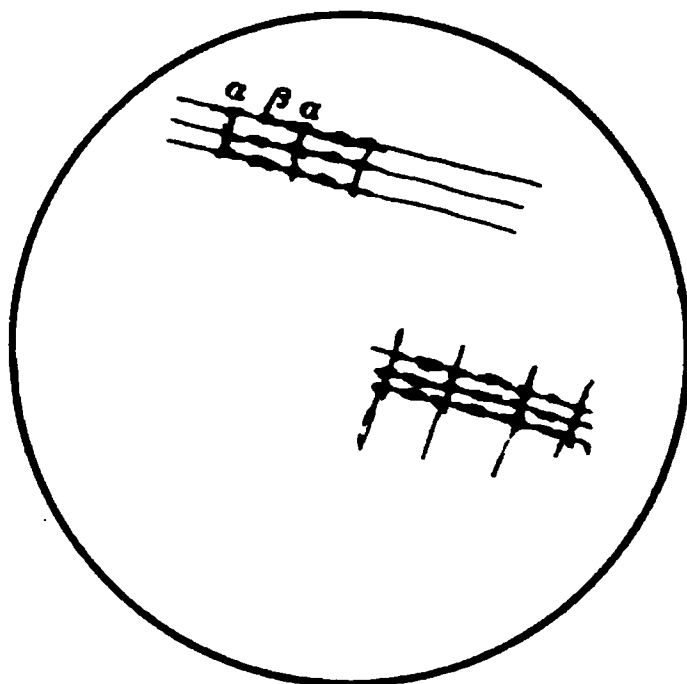
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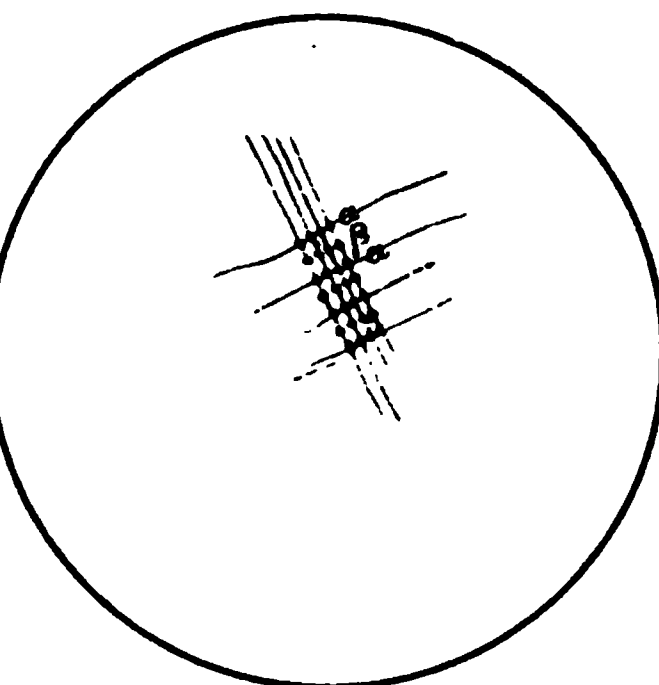
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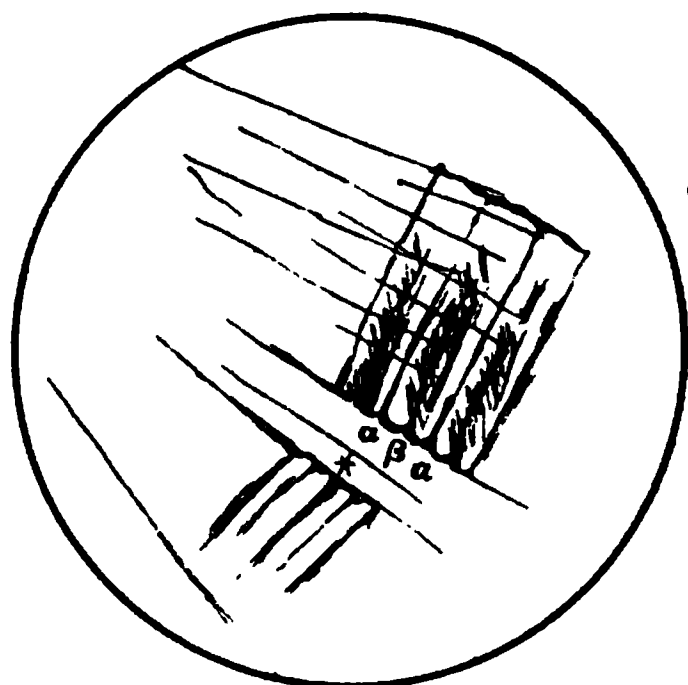
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PLATE XX.

PHOTO 25. A broader sarcostyle in same stage as that in Photo 24.

PHOTO 27. Optical longitudinal section of sarcostyle in stage C (steamed only). The diamond-shaped dots of sarcoplasm on the planes of separation of the bright sarcostyles are in transverse rows at the levels a and β , those at a are slightly the larger.

PHOTO 29. Longitudinal section of fibre in stage C. The sarcoplasm is distributed as in Photos 27 and 28, and is darkly stained with gold. The tissue was embedded in paraffin and is therefore shrunken, so that all the parts appear much smaller than the corresponding parts in Photo 28.

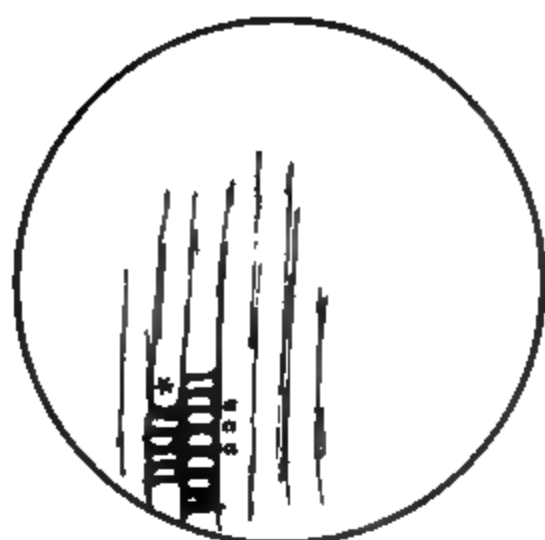
PHOTO 26. Isolated sarcostyle in stage B at the lower part and in stage C at the upper part of the field (chromic and formic acid mixture).

PHOTO 28. Longitudinal section of fibre in stage C (chromic acid and logwood). The stained sarcoplasm is distributed as in Photo 27.

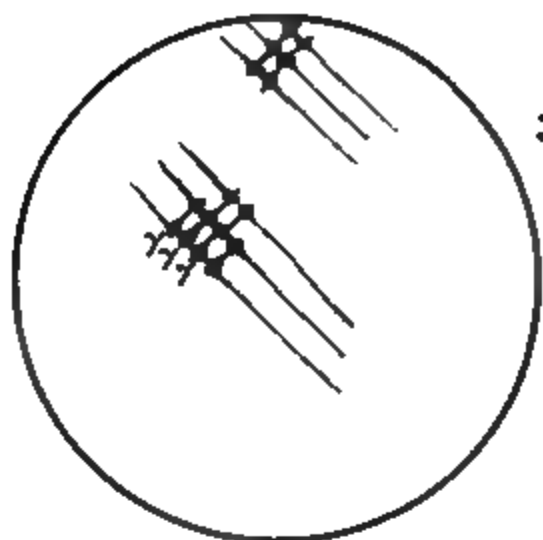
PHOTO 30. Parts of two isolated sarcostyles in stage C, from a fibre fixed with the chromic and formic mixture. At \star the outline of the edge can be seen. Slight shrinkage has occurred, and the upper sarcostyle shows longitudinal wrinkling.

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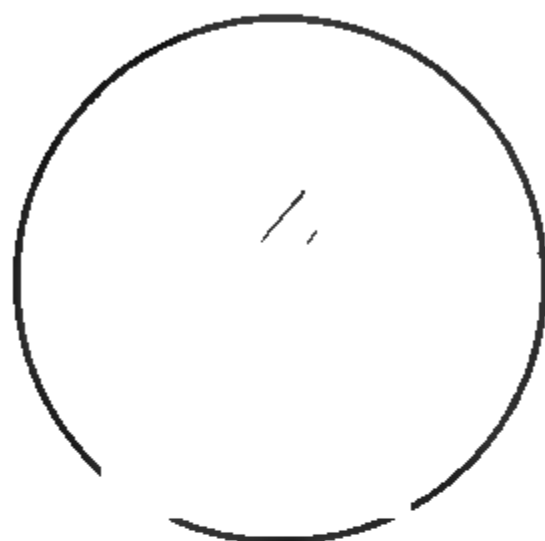
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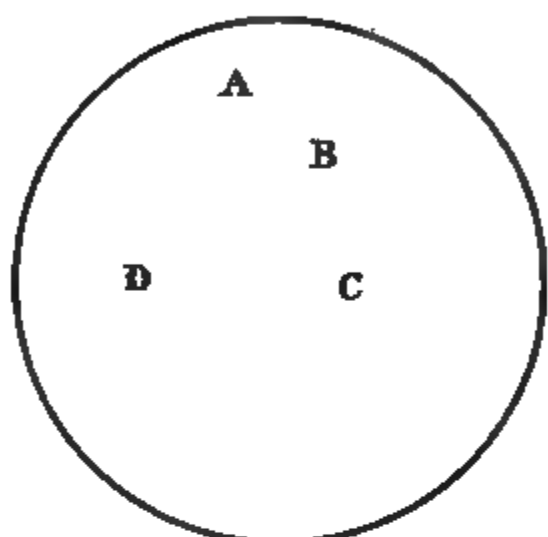
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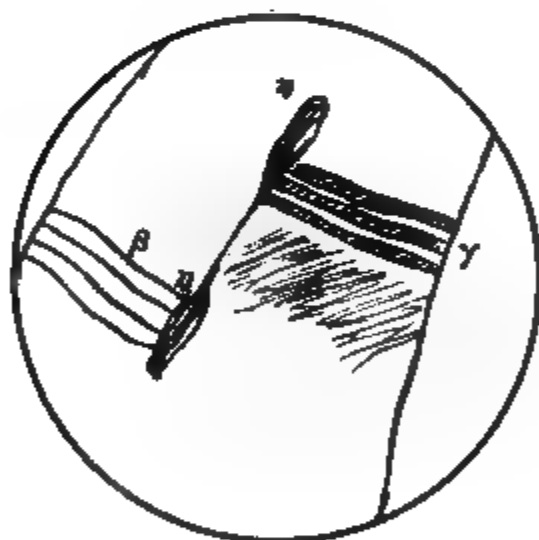
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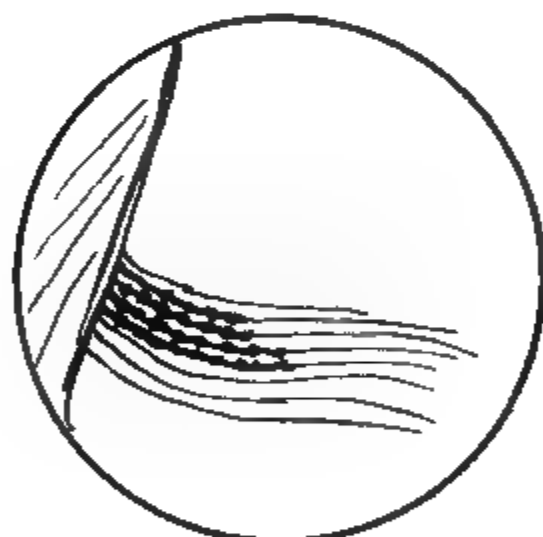
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PLATE XXI.

PHOTO 31. Optical longitudinal section of fibre in stage D (steamed only). At * the outlines of the sarcostyles and their much contracted sarcomeres can be seen. At other parts the focus is not true and the illumination of parts is largely reversed. The state of aggregation of the sarcoplasm is not well shown on account of the longitudinal dislocation of most of the sarcostyles.

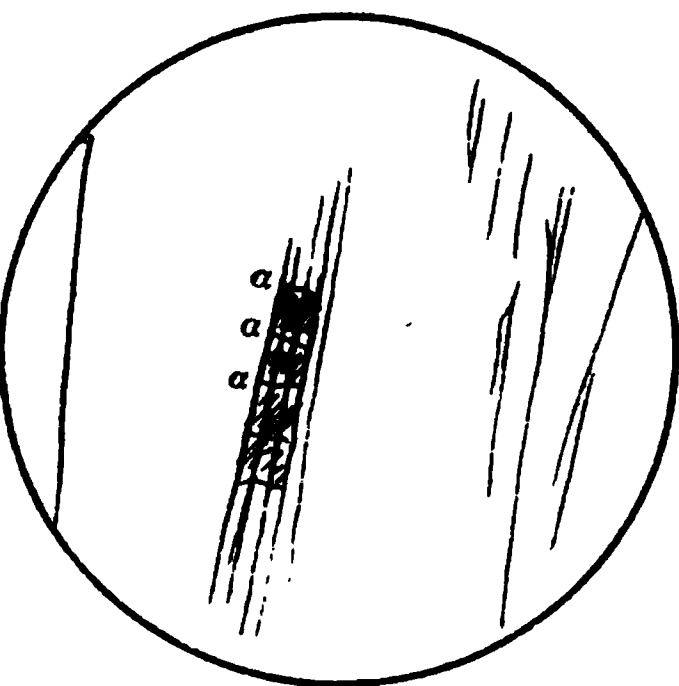
PHOTO 33. Optical longitudinal section of fibre in stage D (chromic acid and logwood). This photograph illustrates the obscure appearance of fibres in this stage, which is usual when there are no longitudinal dislocations.

PHOTO 35. Part of an oval transverse section of a partially contracted fibre (formaline and logwood). The central core with two nuclei at η and η' . The plane of the focus cuts the sarcomeres in different parts of their length so that the three appearances of different foci (see text) are shown at a. b. γ . The

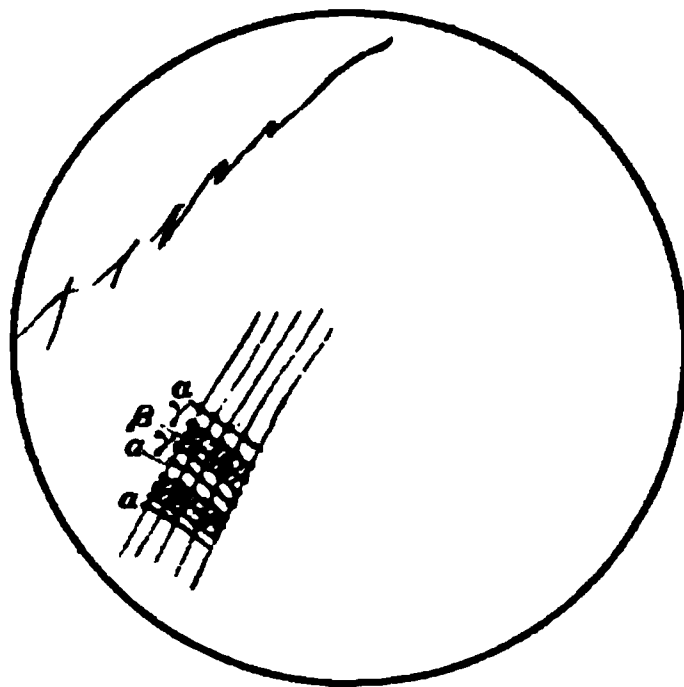
PHOTO 32. Same as 33, but the sarcoplasm is better shown in large diamond-shaped masses between the constricted parts of the sarcostyle. Owing to the shrinkage caused by the fixing agent, the thickness of the sarcostyles is less than in Photo 43.

PHOTO 34. Optical longitudinal section of a steamed fibre showing all stages of contraction in the one field. (At A, B, C, D.) The part in stage B is the most obscure.

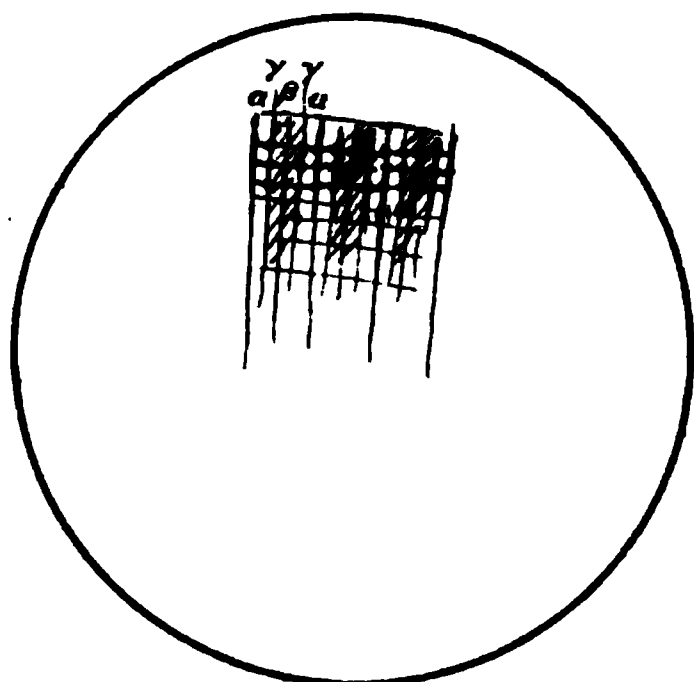
PHOTO 36. Part of a transverse section of a fibre fixed with chromic acid and stained with logwood. The well-marked and regular foldings of the wall due to shrinkage are shown.



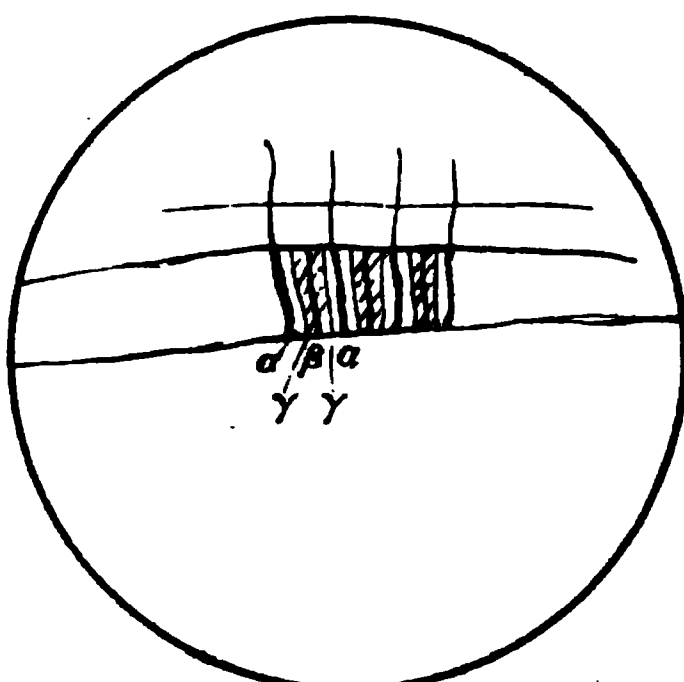
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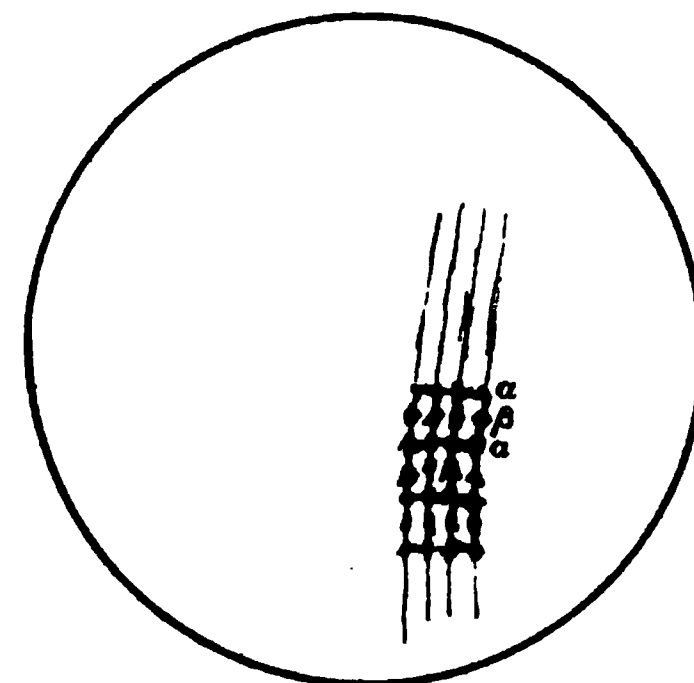
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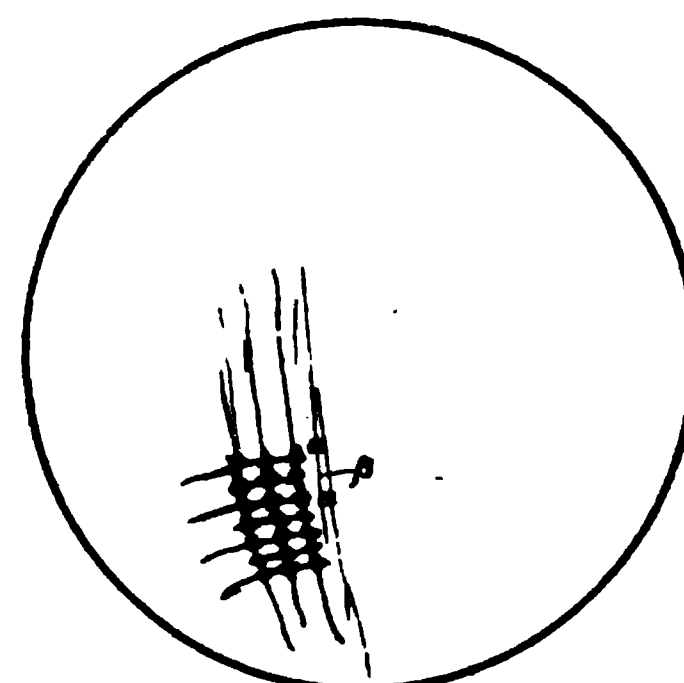
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PLATE XXII.

PHOTO 37. Longitudinal section of a fibre of the belly-muscle of the rat in stage A (formaline and logwood). The α septa appeared doubled through inaccurate focussing.

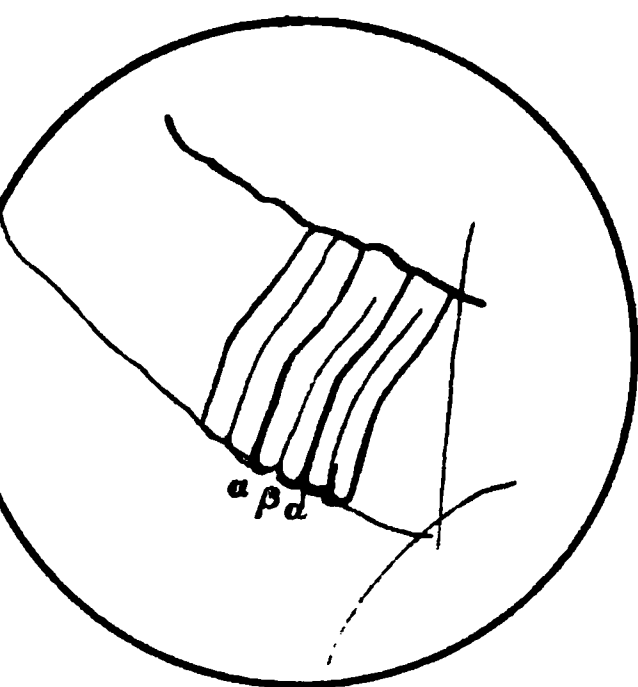
PHOTO 39. A longitudinal section of fibre of the belly-muscle of the rat in stage B (formaline and logwood). The section is almost in the plane of the lamellar sarcostyles, so that the appearance is almost like that of the flat surface of an isolated sarcostyle in this stage.

PHOTO 41. Longitudinal section of a fibre of the frog's sartorius muscle in stage C (formaline and logwood).

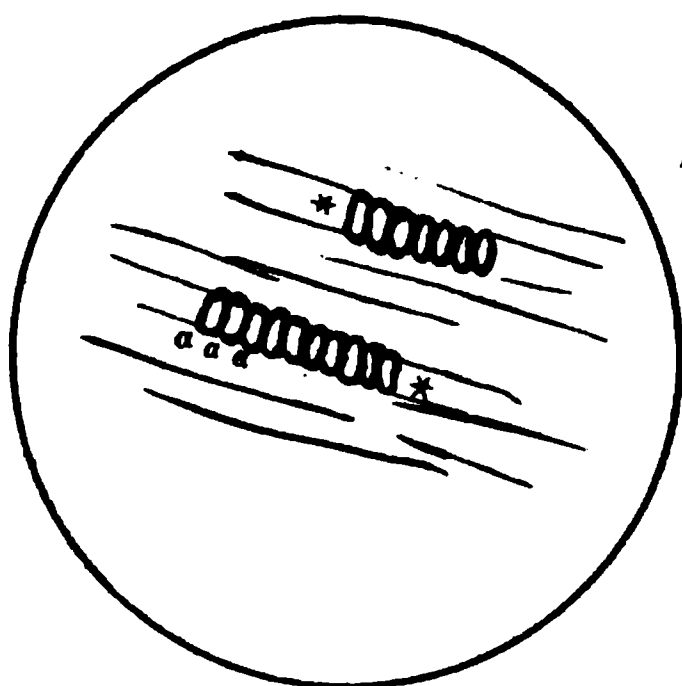
PHOTO 38. Longitudinal section of a similar fibre in stage B. The sarcoplasm is not in continuous lines between the sarcostyles as in Photo 50, but is aggregated in tiny dots between the constrictions of the sarcostyles caused by the $\alpha\beta$ and γ discs.

PHOTO 40. The free border of a partially isolated sarcostyle of a fibre from the sartorius of the frog. (Chromic and formic mixture, unstained). It is in a late B stage, so that the α lines are very faintly marked. The halos of the septa are more marked on the right than the left side owing to obliquity of the plane of the septa. It is overlapped by other similar sarcostyles.

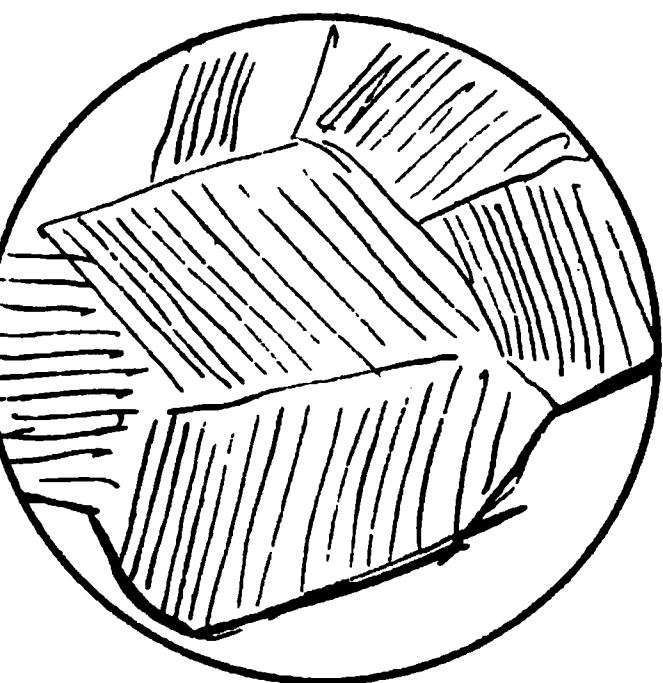
PHOTO 42. Optical longitudinal section of similar fibre (steamed only). There is considerable longitudinal dislocation of parts so that the outlines of the individual sarcostyles can



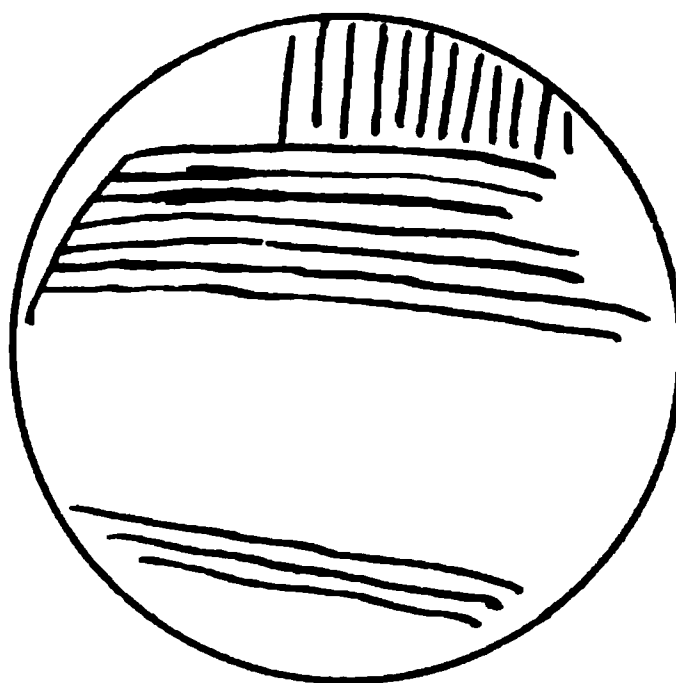
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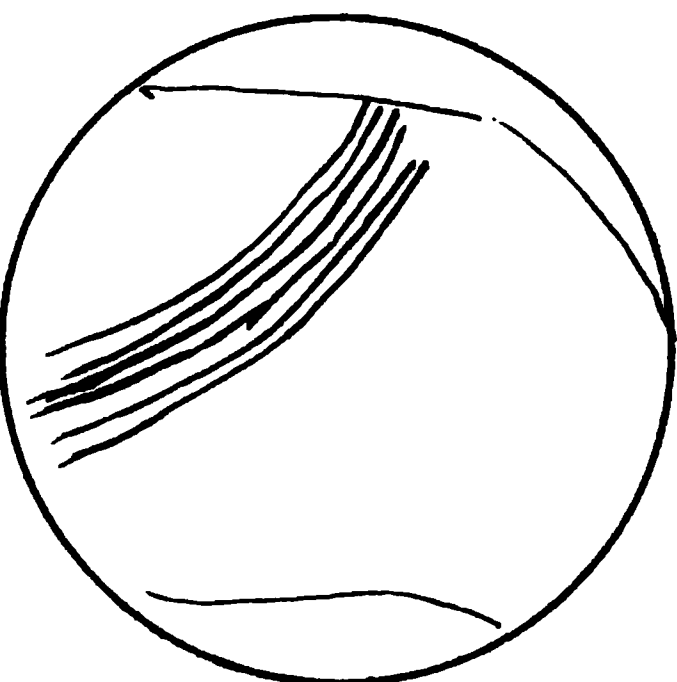
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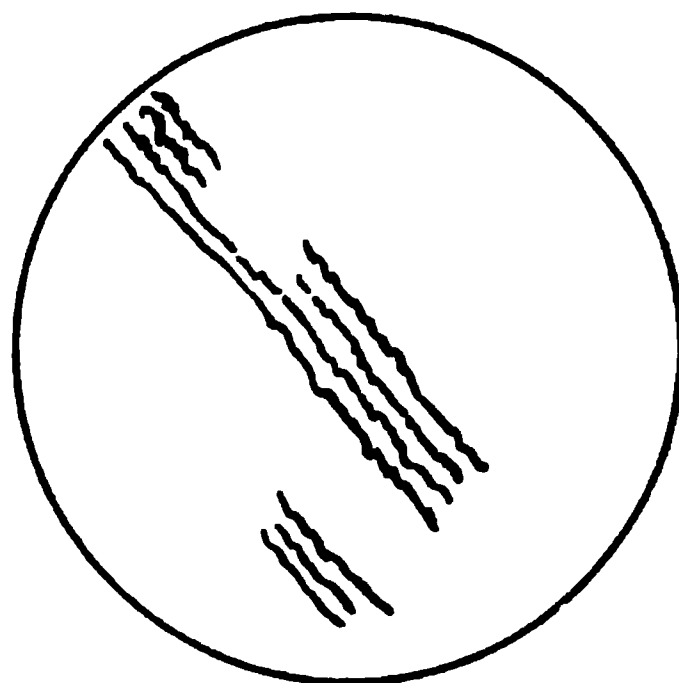
45



46



47



48

PLATE XXIII.

PHOTO 43. Parts of two isolated sarcostyles in an early C stage (chromic and formic mixture). There are no well marked longitudinal wrinkles. Cf. with Photo 30.

PHOTO 45. The greater part of a transverse section of a fibre from the belly-muscles of the rat (formaline and logwood). The unstained narrow sections of the sarcostyles are separated by thin lines of staining sarcoplasm, and are arranged in five distinct systems in this fibre. This magnification is only about 500 diameters.

PHOTO 47. Transverse section of a fibre from the frog's sartorius muscle (formaline and logwood); at one part there has been some shrinkage and a consequent wrinkling of the walls of the sarcostyles.

PHOTO 44. Optical longitudinal section of a fibre from the frog's sartorius muscle in stage D (steamed only). There is considerable longitudinal dislocation of many of the sarcostyles. The shape and outline of the contracted sarcomeres can be seen at *

PHOTO 46. The central part of Photo 45 magnified rather more than 1,000 diameters.

PHOTO 48. Part of a transverse section of a fibre from the frog's sartorius contracted (chromic acid and logwood). The walls of the sarcostyles are longitudinally wrinkled owing to the shrinkage caused by the chromic acid, and therefore appear more or less zig-zagged. Cp. with Photo 36.

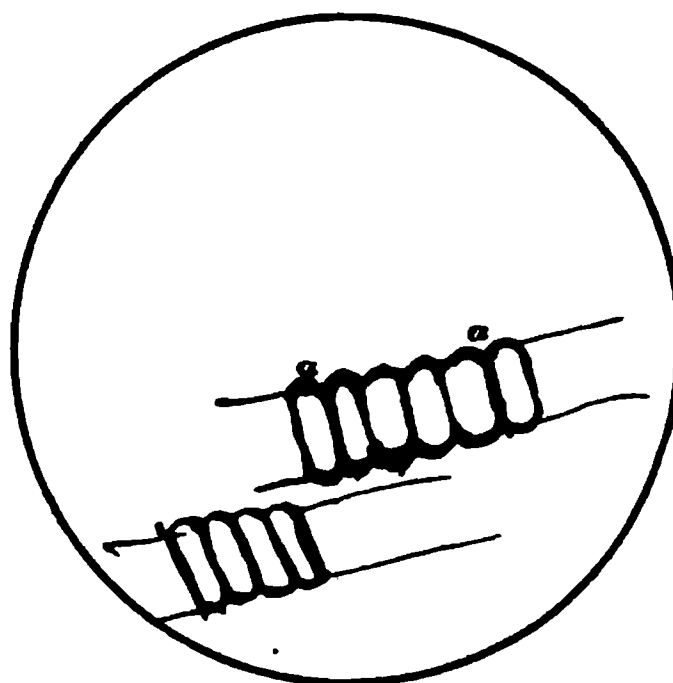
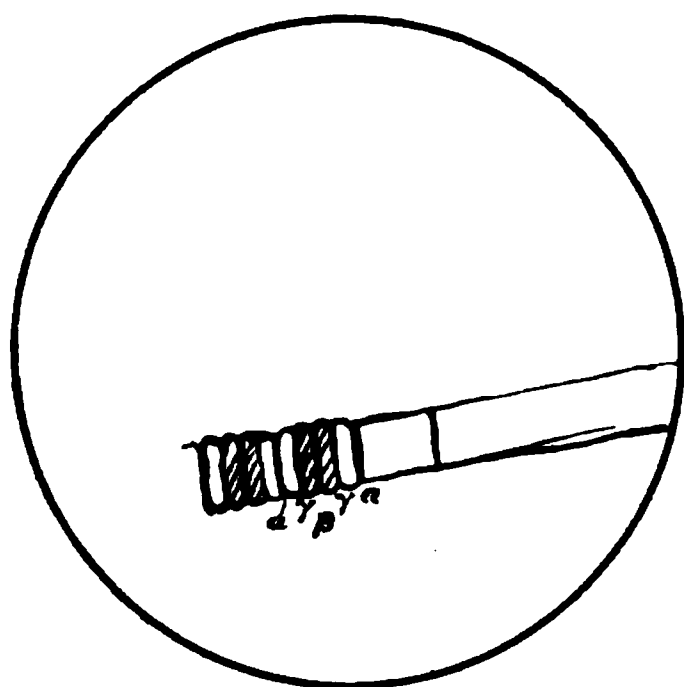
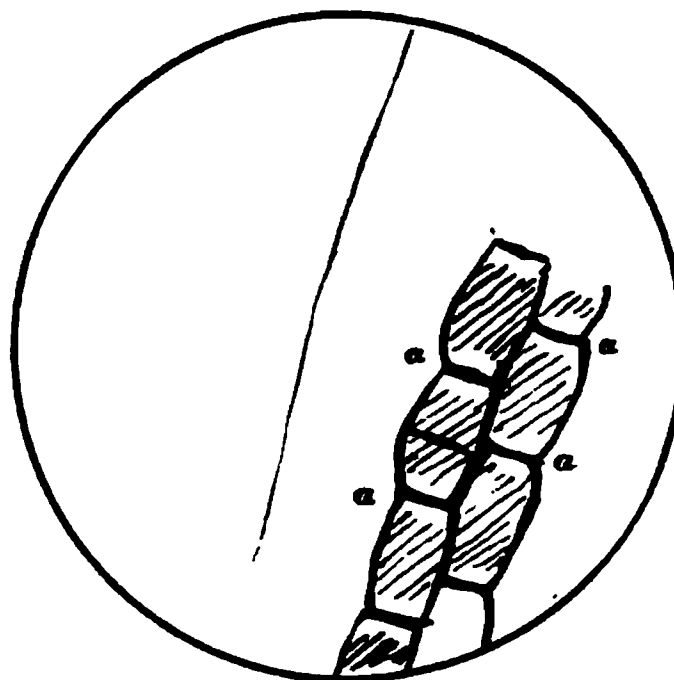
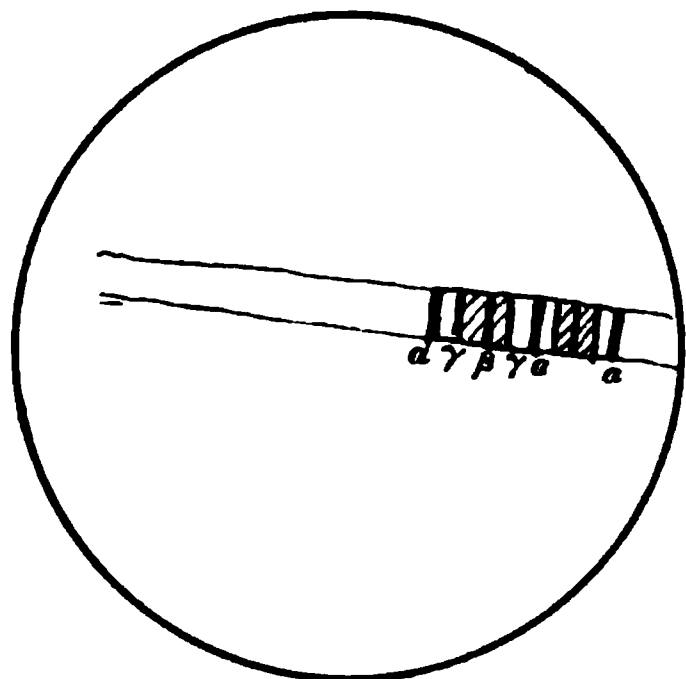
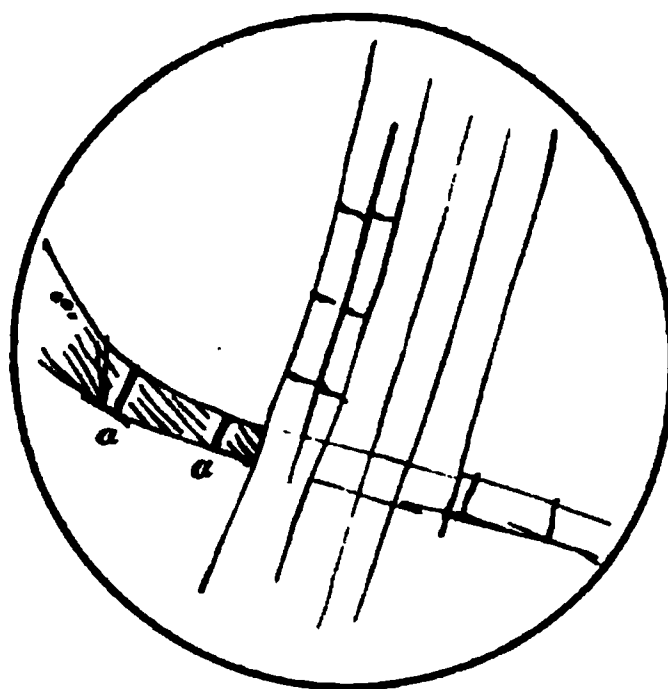
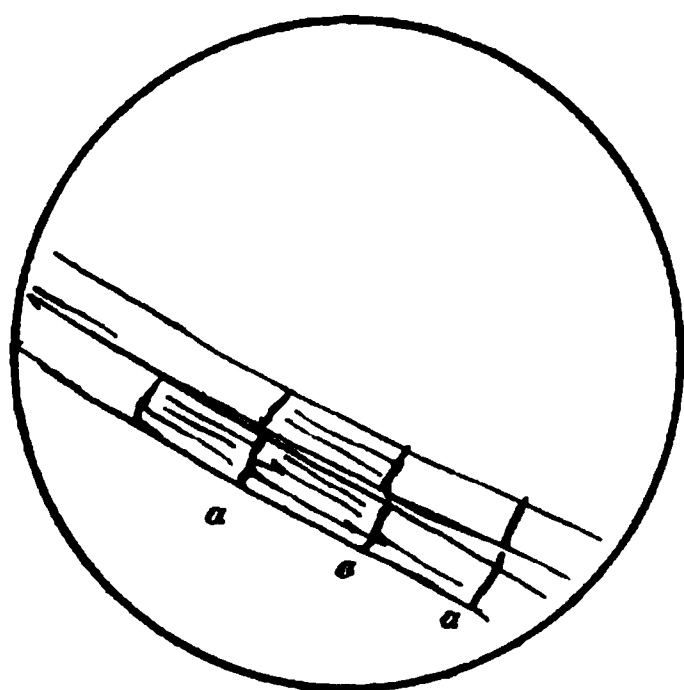


PLATE XXIV.

PHOTO 49. Two large sarcostyles of the muscles of the large claw of the crayfish. These and all isolated sarcostyles of the following photographs were prepared with chromic acid or formaline, followed by formic acid, as described in the text. These two sarcostyles are stained with logwood and shew longitudinal foldings of the walls of the sarcomeres.

PHOTO 51. Small fibril in stage A, stained with logwood. All the discs are well stained and the γ discs appear as well marked as the α discs. Cp. with Photo.

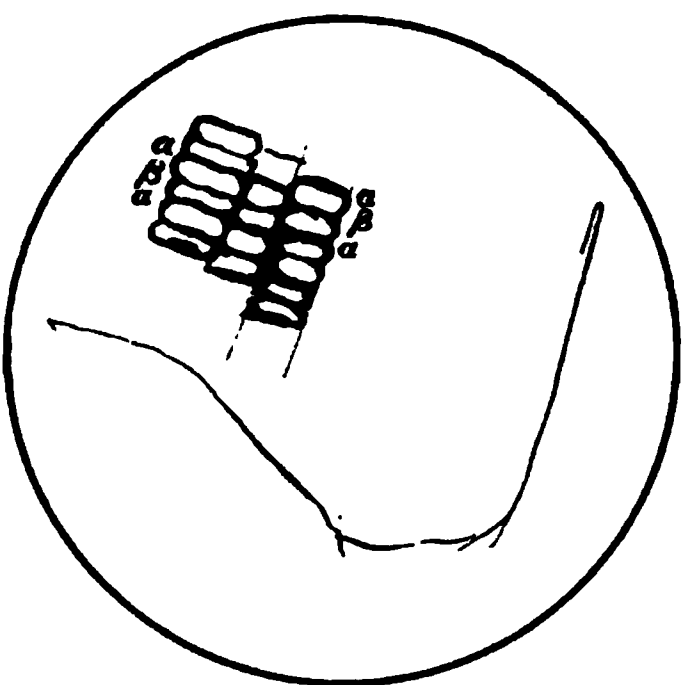
PHOTO 53. Small sarcostyle in stage B. The wall and all the discs are stained with logwood. The four bulged segments of the wall in each sarcomere can be seen.

PHOTO 50. Similar sarcostyles to those of Photo 70, but they are unstained and shew the halos of the α discs.

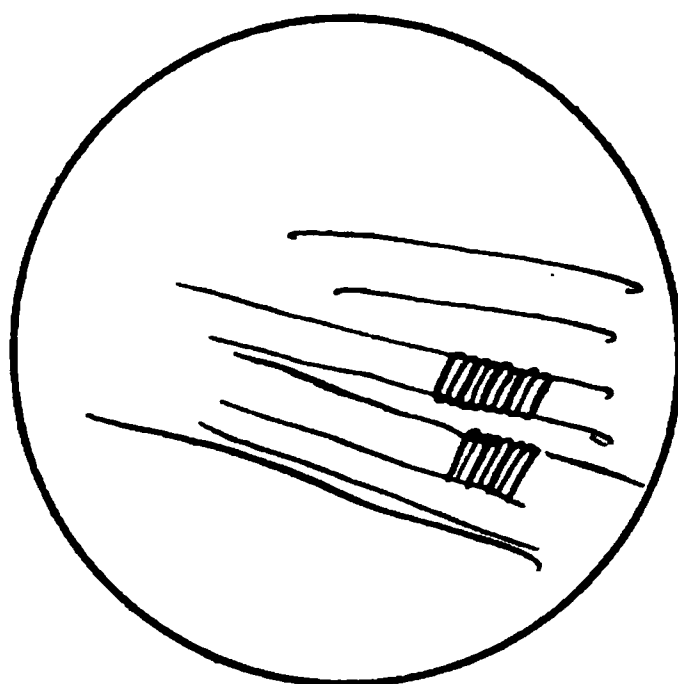
PHOTO 52. Large sarcostyles in stage A, *en masse*, but with many longitudinal dislocations. Prepared by the ordinary gold method.

PHOTO 54. Large sarcostyles in stage B, *en masse*. All the discs appear almost equally dark.

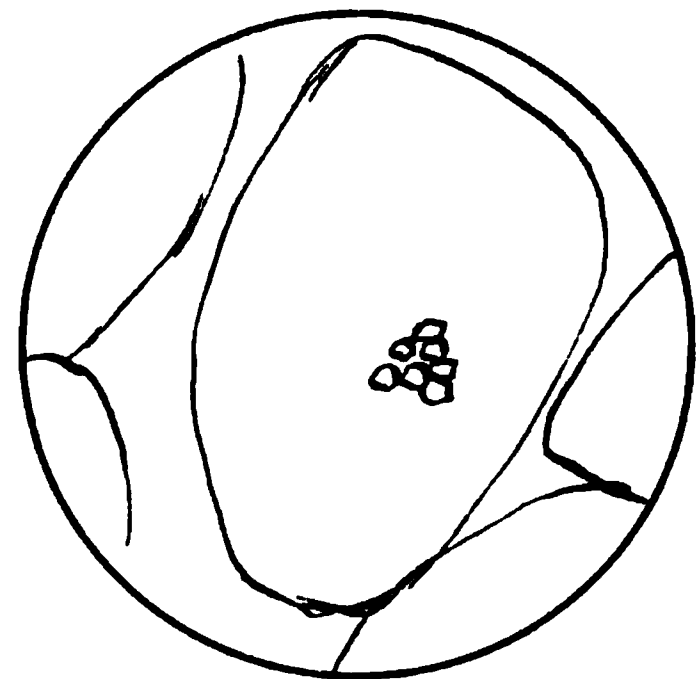




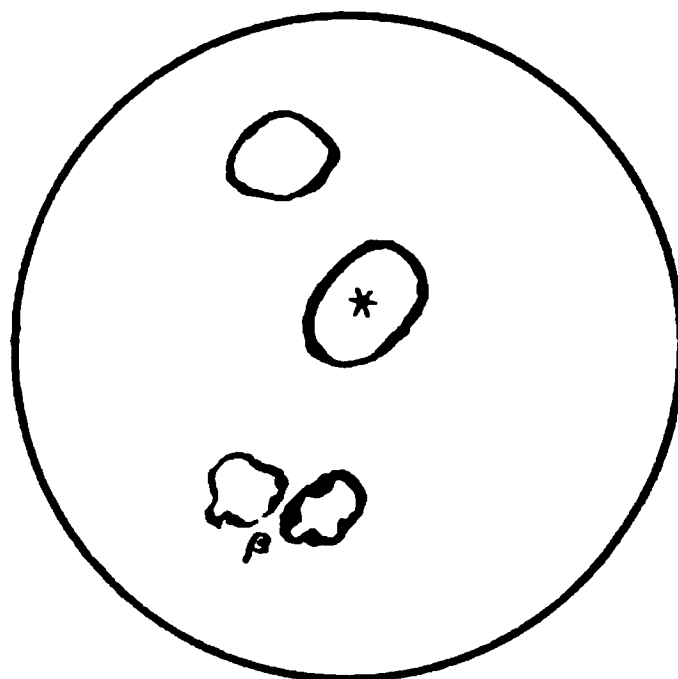
55



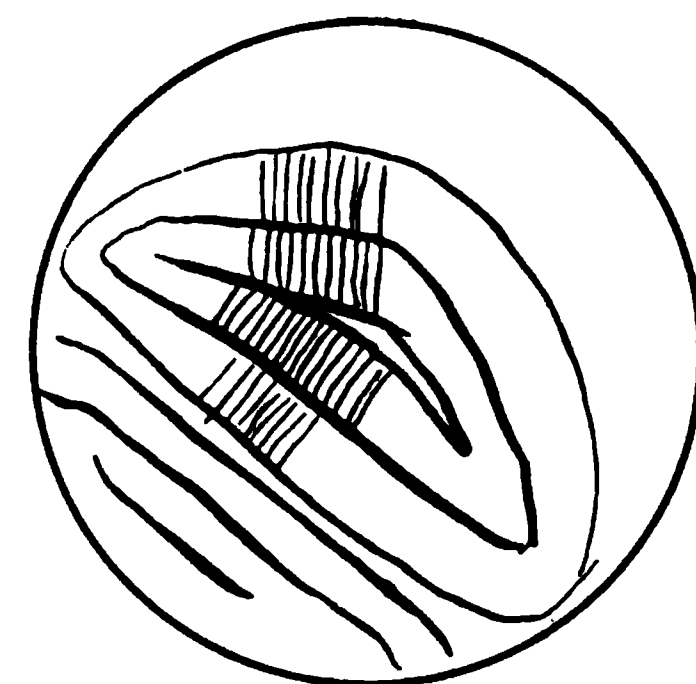
56



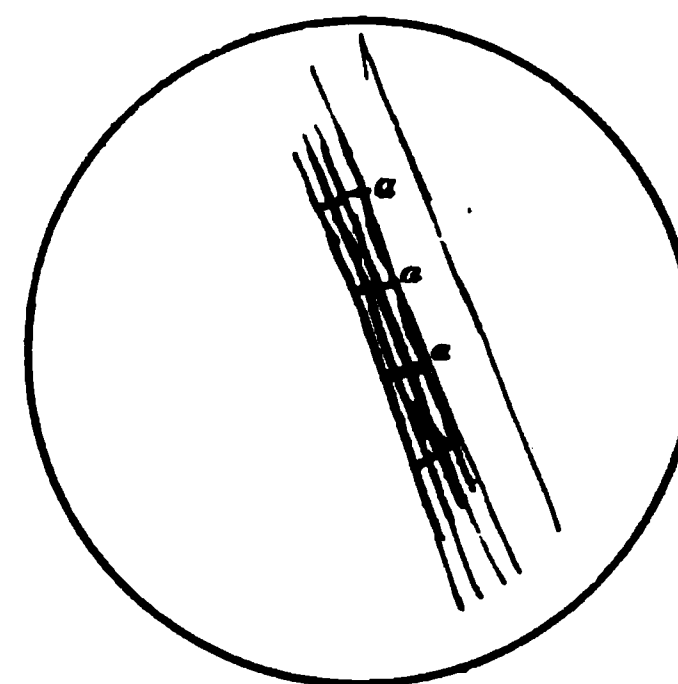
57



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PLATE XXV.

PHOTO 55. Longitudinal section of large sarcoptyles *en masse*, in stage C, fixed with chromic acid and stained with logwood. The outline of the walls of the sarcomeres characteristic of stage C is well shown.

PHOTO 57. Transverse section of the claw-muscle prepared by the method of soaking in white of egg described in the text, and stained with logwood. The magnification is only about 100 diameters.

PHOTO 59. Transverse sections of two fibres of the leg-muscle of the house-fly (formaline and logwood). Each one shows two concentric rings of radially arranged narrow sarcoptyles, separated by the lines of stained sarcoplasm.

PHOTO 56. Several partially isolated small sarcoptyles in a late C stage, stained with logwood. The outline of the wall is faintly indicated.

PHOTO 58. Similar transverse section of a fibre with large sarcoptyles. The darkly stained wall with a faint refraction halo is shown at * and at p a section of a sarcoptyle shows a deeply indented wall like those in photo.

PHOTO 60. Longitudinal section of a fibre of the leg-muscle of the common house-fly fixed with formaline in stage A. The *a* discs and their halos are shown in parts. Cp. with Photos 19 and 37.

PROCEEDINGS OF THE
ANATOMICAL SOCIETY OF GREAT BRITAIN
AND IRELAND.

JULY 1896.

A SUMMER MEETING was held in the Anatomical Department of Oxford University on Saturday, July 6th, 1896, at 4 P.M.

Professor THANE was in the chair, and thirty-three members and visitors were present.

PETER THOMSON, M.B., B.Ch. Vict., Demonstrator of Anatomy in Owens College, Manchester, was elected a member of the Society.

Professor A. THOMSON demonstrated specimens of different *varieties of the Pelvis of the Kidney*, also specimens of *Spleens showing rudiments of a right lobe*, and the *cardiac end of a Stomach*, in which the mucous membrane round the orifice showed indications of a spiral twist, a condition which Professor Thomson regarded as possibly adding to the security of the cardiac orifice.

Dr FARMER showed two specimens of *double Inferior Vena Cava*, and two *Temporal bones* in which the lateral sinus was further forward than usual, and only separated from the surface by a very thin plate of bone.

The Insular District in the Cerebrum of the Anthropoid Ape.

Professor D. J. CUNNINGHAM read a paper on the insular district in the cerebrum of the anthropoid ape. He pointed out that whereas the insula in man is completely covered over by the four opercula, in the

anthropoid ape only the posterior part is so concealed. The anterior part of the simian insula is free and exposed on the surface, and stretches forward as far as the fronto-orbital sulcus, which is to be regarded as a furrow corresponding to the anterior limiting sulcus of Reil in man. This exposure of the front portion of the insula in the ape is due to the absence of the frontal and orbital opercula. This interpretation of the insular region is now very generally accepted, and an overwhelming array of facts can be brought forward in support of it. One link in the chain of evidence, however, is still defective, and the object of the present paper is to supply this. In man the insular district is known to occupy a surface area closely corresponding to the subjacent caudate and lenticular nuclei. The anterior limiting sulcus of Reil lies immediately over the anterior end of the caudate nucleus, whilst the posterior end of the insula extends back as far as the hinder end of the putamen of the lenticular nucleus. Professor Cunningham showed, by means of the lantern, a number of horizontal and coronal sections through the cerebrum of the chimpanzee and the orang. By these it is clearly proved that the submerged hinder part of the insula of the ape corresponds only with the lenticular nucleus, and does not extend as far forwards as the anterior end of the caudate nucleus. This submerged portion of the ape's insula cannot be regarded, therefore, as the equivalent to the entire insula in man. On the other hand, when we take the exposed part of the simian island of Reil into account, it is seen that the fronto-orbital sulcus has precisely the same position in relation to the caudate nucleus that is occupied by the anterior bounding furrow of Reil. Marchand, to some small extent, has already tapped this source of evidence in the brain of a lower ape, and also, in an imperfect manner, in the orang.

Professor Cunningham called attention to the great amount of variation to which the insular region of the chimpanzee is subject, and specially drew attention to the fact that in some cases a decided advance is made towards the condition found in man. He showed a series of photographs by means of the lantern, which exhibited a regular gradation in this direction. He believed that these brains showed, in a graphic and remarkable manner, the lines along which the phylogenetic evolution of the human brain had taken place, and this he regarded as being rendered all the more striking by the fact that we occasionally meet with a human brain which in this respect is arrested in its development at a stage corresponding closely to the highest stage of development attained by the chimpanzee brain. He exhibited the photograph of such a cerebrum. This paper will shortly be published in full.

Dr AMBROSE BIRMINGHAM exhibited a *model of the Abdominal Viscera*, and described the chief points of interest. A full description of this model will be found on p. 97 of the *Journal of Anatomy*.

Dr T. H. BRYCE read the following *Note on a Case of Pectoralis minimus*.

This muscle is one of the rarer forms of variety in human myology.

Professor Macalister (1), in his *Catalogue of Muscular Varieties*, says, "pectoralis minimus is described by Professor Gruber (*Mem. de l'Acad. Imp. de St Petersburg*, series vii. tom. iii.), and was previously remarked by Böhmer; it lies superficial to the costo-coracoid membranes and is attached internally to the 1st rib—to the external border of the rhomboid ligament, and by a few fibres to the manubrium sterni—it passes outwards superficial to the pectoralis minor, to be inserted into the coracoid process; this is also noticed by Rosenmüller; it seems like an outward extension of the preclavicularis medialis." This latter is a fusiform muscle, passing superficial to the subclavius outside the costo-coracoid membrane from the cartilage of the 1st rib, anterior sterno-clavicular ligament, sometimes from the manubrium, to the lower border of the clavicle in its middle third. It has been described extending to the outer third, even to the coracoid process.

There is yet another muscle passing from the manubrium and cartilage of the 1st rib—the "tensor semivaginæ articulationis humero-scapularis" of Gruber (2). It lies between the pectoralis major and minor, passes below the coracoid process, and is attached to the fascia over the shoulder-joint known as the semivagina.

The instance I have to record occurred on the right side of a female subject (the same in which was found the deep accessory peroneal nerve). It arose as a narrow fleshy band from the cartilage of the first rib, just internal to the tendon of origin of the subclavius, from the edge of the manubrium sterni, between the first and second costal cartilages, and slightly from the upper border of the second costal cartilage at its sternal end.

From this origin it passed over the costo-coracoid membrane and the pectoralis minor to the coracoid process, where it expanded into a wide aponeurosis. This extended over the process, was slightly attached by its under aspect to its tip, but was in direct continuity with the fascia over the shoulder-joint. This part of the fascia, strengthened by the fibres from the tendon, had definite attachments: upwards, it was attached to the anterior border of the clavicle, internal to the coraco-clavicular ligament; below, it passed downwards over the coraco-brachialis; backwards, it passed, first, over the upper surface of the coraco-acromial ligament, with which it was intimately connected, to be continued as a delicate layer over the supraspinatus muscle; 2nd, over the subacromial bursa and capsule of the joint, to be continuous with the thin deeper layer of the fascia over the infraspinatus muscle under the deltoid.

Unfortunately, I was unable to determine its nerve supply, as its nerve was cut before my attention was directed to the muscle.

Professor Windle (3) found the pectoralis minimus in two cases supplied by the external-anterior-thoracic nerve.

Knott (4) described two cases in which the muscle arose from the 1st rib cartilage alone.

The muscle in the present instance corresponds exactly to none of the

muscles described as arising from the 1st rib cartilage and manubrium. It is attached slightly to the tip of the coracoid process, not to its inner border, as is the pectoralis minimus proper. It passes over, not under, the process, as in the "tensor semivaginae." If, with Professor Macalister, we regarded the pectoralis minimus as an extension outwards of the præclavicularis medialis, then the present muscle is a further extension outwards of the minimus; while the "tensor semivaginae" would be a still further extension outwards of the same muscle.

Professor Windle (3) regards the pectoralis minimus as the representative in man, of what he terms the deep manubrial radial division of the pectoral sheath, supplied by the anterior thoracic nerve. He says: "It (i.e. deep manubrial) is rather an inconstant muscle, the group in which it is most generally existant being the Carnivora. It arises beneath the superficial manubrial from the edge of the manubrium and adjacent parts of the 1st rib, and passes as a narrow strap-shaped muscle either to the head of the humerus, the coracoid process of the scapula, or possibly occasionally to the fascia over the supraspinatus, or other parts of the posterior surface of the scapula."

If we accept strictly the radial divisions of the pectoral sheet into manubrial, gladiolar, &c., it seems necessary to include as deep manubrial such a slip, as I have noted several times in dissecting the pectoralis major in the human subject. The highest costal origin of the sternal part in these cases arose from the 1st rib cartilage and the edge of the manubrium as a separate slip, which crossed the costo-coracoid membrane and pectoralis minor, partially fused with the gladiolar part, and was inserted with it into the upper part of the humeral attachment. Between it and the second costal origin there passed, in one case, a large branch of the external anterior thoracic nerve into the substance of the pectoralis major.

If, therefore, we regard this highest separate costal slip as deep manubrial, we have in it, in the pectoralis minimus, and in the muscle I have described, representatives of all the insertions which Professor Windle describes for the deep manubrial muscle; and if we added the præclavicularis, we might have represented in man, by a variety of vestigial slips, such a deep manubrial as is found in the superficial part of the sterno-scapularis of the rabbit, i.e., that part supplied by the anterior thoracic nerve.

Regarding this sterno-scapularis, however, and indeed the whole group of muscles arising from the 1st rib cartilage, there is much doubt, owing to the difficulty of distinguishing between elements derived from the subclavius and those derived from the pectoral sheet, so that Professor Windle only doubtfully includes the part of the sterno-scapularis supplied by the anterior thoracic nerve, as representing in its entirety the deep manubrial.

The instance described above of a muscle arising from the manubrium and 1st costal cartilage, and inserted into the fascia which passes over the head of the humerus to the dorsum of the scapula, as well as to the clavicle, is interesting in connection with such a muscle

as the sterno-scapularis, and may possibly be, as I have hinted, invested with some morphological value.

Works referred to.

1. MACALISTER, *Trans. Roy. Irish Acad.*, vol. xxv. p. 51.
2. VIRCHOW, *Archiv.*, vol. xl. p. 430.
3. WINDLE, *Trans. Roy. Irish Acad.*, vol. xxix.
4. KNOTT, *Proc. Roy. Irish Acad.*, s. ii. vol. iii. p. 417.

Dr T. H. BRYCE gave a demonstration of a *long muscular branch of the Musculo-Cutaneous Nerve of the Leg*, and read the following paper:—

The usual arrangement of the muscular branches of the musculo-cutaneous or superficial peroneal nerve is as follows:—Immediately on parting company with the anterior tibial, a branch, sometimes two branches, come off, which enter directly the substance of the peroneus longus. The main nerve passes downwards in the peroneus longus close to the bone, and generally gives off another branch to that muscle from its anterior aspect. About the junction of the upper and middle thirds of the leg, the branch for the peroneus brevis comes off from the posterior aspect of the nerve, which is now tending inwards to reach its position between the peronei and the ext. longus digitorum. This branch is directed straight downwards, and breaks up into twigs for the peroneus brevis; but there is sometimes a nerve which has a longer course, and is worthy of special description.

It was found in four extremities out of twenty examined, and in each case a peroneus quartus was present,—in two cases well developed, in the other two as a thin slip. It came off along with the nerve for the peroneus brevis, ran in the substance of that muscle, close to the external border of the fibula. In the lower third it came to view on the posterior surface of the muscle, and was closely applied to the peroneus quartus, which it supplied.

In one instance this latter muscle was exceptionally large. It arose from nearly the whole lower half of the external border of the fibula by an aponeurosis which was common at the upper part, to it and the brevis, where, indeed, the quartus was intimately connected with the brevis. Moreover, it overlapped the brevis, lying lateral and superficial to it. The muscular belly was 12 cm. long and 2 cm. broad, and ended in a tendon which was attached to the outer side of the os calcis, below and behind the peroneal groove. There was, in addition, the usual slip to the fifth toe from the tendon of the brevis, from which also a tendinous slip passed to the fascia over the fourth interosseous space.

In each case the nerve supplied the muscle, but did not end in it. In two extremities it was traced to the outer side of the os calcis, where it was lost below the peroneal bands. In the other two ex-

trемities it was followed below these, under the peronei tendons, to their inner side, where it lay along the outer border of the extensor brevis digitorum. It broke up into a number of twigs, which ended in the muscular substance of the outer slip of the muscle; but some filaments were traced along the 4th interosseous space, as far as the base of the 4th metatarsal bone, where they were lost in the ligaments attached to it.

This nerve, so far as I can find out, seems to have escaped notice, as a variety in the distribution of the musculo-cutaneous, for it is not given in any of the text-books, nor in such of the special papers on the morphology of the peroneus brevis, and extensor brevis digitorum as I have had access to, nor does Ruge (1) mention it in his memoir on the extensor muscles. In that memoir he described very completely the distribution of the peroneal nerve in many of the mammalian orders, to elucidate the morphology of the extensor group of muscles. I must briefly review his results, to throw light on the relations of the nerve I have described.

In *Ornithorhynchus* the short extensors of the toes arise from the fibula, and are the extensor brevis dig. I-IV, and the extensor brevis, dig. V. The peroneal nerve divides into a superficial cutaneous branch, and a deep muscular: with the latter we are alone concerned. It gives off branches to the peroneus longus, ext. br. dig. V, and the ext. brev. dig. I-IV; the branch to the last named passes down its lateral border, and can be traced to the tarsus. The deeper branch passes further inwards, and supplies the extensor longus digitorum and the extensor longus hallucis, in which the nerve ends.

In the Marsupialia the ext. brev. hallucis lies on the dorsum of the foot, while the extensor brev. dig. II-IV and ext. brev. dig. V arise from the fibula (fig. 1). Professor Cunningham (2) has described the distribution of the nerves in *Thylacine* and *Cuscus*. He says that the peroneal nerve divides into a superficial purely cutaneous branch, and a deeper muscular and cutaneous branch corresponding to the anterior tibial. From the latter all the muscular branches arise: one of these he notes as a long slender branch, passing downwards to supply the lower portions of the ext. brevis.

Ruge, in *Didelphys Virginia* (fig. 1), describes the peroneal nerve, dividing into a superficial purely sensory branch, and a deeper, which passes between the two heads of the peroneus longus, and breaks into many branches, motor and sensory. The branch for the peroneus longus goes direct to the muscle; the branches for the peroneus brevis and the extensor brev. dig. II-IV pass between the short extensor of the V and that of the IV toe. Along the lateral border of the ext. brev. dig. II-IV there runs to the central fourth of the leg a fine stem to this muscle; the nerve to the long extensor passes underneath the tendinous origin of the peroneus brevis, while between the fibular and the mesial muscles runs the nerve to the tibialis anticus, which, as the deep peroneal or anterior tibial, reaches the extensor brevis hallucis on the dorsum of the foot, after supplying the extensor longus hallucis. The stem to the extensor brevis dig. II-IV, Ruge regards as homologous

with the long branch to the same muscle in *Ornithorhynchus*, which reaches, however, the tarsus in that case.

Among the Rodentia, the rabbit has two short extensors arising from the leg,—the ext. dig. IV and V, or peronei dig. IV and V. Their muscular bellies are confined to the proximal part of the leg, and to them the nerves pass off from the peroneal in a bunch—there is no special long branch; but in *Myoxus*, Ruge has described a nerve



FIG. 1.—*Didelphys Virginiana* (after Ruge).

supplying these muscles, and running behind the external malleolus to the outer side of the foot and 4th interphalangeal space. In *Cavia* the corresponding nerve ends on the metatarsus.

Among the Carnivora, I have dissected the nerve in *Felis dom.* (fig. 2) and *Lutra vulgaris*. In the former the nerve for the extensor brevis dig. V, which is now the only element of the short extensor series arising from the fibula, comes off in common with the nerve for the peroneus brevis, from the superficial peroneal, now the musculo-cutaneous of human anatomy. It gives first a twig to the extensor brev. dig. V, and, a little lower, two or more to the per. brevis, and then passes between these two muscles to the back of the peroneus brevis. On this it is continued down to the external malleolus, behind which it passes along the outer face of the os calcis, under

Per. Lor

Ext. Quint. Dq

Sup. Per. 1

Access. Per. N

Per. Brevi

Access. Per. N

FIG. 2.—*Felis domestica* (after Rupe).

the peroneal tendons. It appears on their inner side, on the outer border of the extensor brevis digitorum, in which it breaks up. The anterior tibial nerve ends below the inner part of the extensor brevis, which it supplies. In *Lutra* the nerve gives off a superficial branch over the dorsum of the foot above the external malleolus, then passing behind this process it lies along the outer border of the extensor brev. dig. to reach the cleft between the 4th and 5th toes.

Ruge thus sums up the arrangement of this nerve, which he calls the deep accessory peroneal nerve in the Carnivora:—

"The muscular branch for the peroneus brevis and ext. brev. dig. V passes on the mesial aspect of the latter, goes between them, and runs as the deep accessory peroneal nerve to the dorsum of the foot, where it may supply the extensor brevis digitorum"—as in *Felis dom.*, *Felis leo* and *Meles*—"or distribute itself to the skin of the sides of the toes (4th and 5th)," as in *Nasua socialis*, "or it may end in the middle of the tarsus, or even in the leg," as in *Mustela*.

Among the apes, in the Simiidae there is usually an extensor brevis quinti dig.: in certain Catarrhines it arises from the proximal part



FIG. 3.—*Ateles paniscus* (after Ruge).

of the fibula, as in Carnivora, &c.; while in the Platyrrhines, in *Cebus* and *Ateles*, it comes from the distal fourth. In the latter Ruge described a specimen in which it was present on one side, fused with the peroneus brevis on the other.

In the case of the lower origin of the ext. br. dig. V, as in *Ateles* (fig. 3), the branch for the muscle comes off from the superficial

peroneal, and forks on the proximal aspect of the peroneus brevis into two branches—an anterior for the peroneus brevis, a posterior for the ext. brev. dig. V. In the case of *Cebus*, where the latter muscle was fused with the peroneus brevis, the nerve ended in it. In the anthropoid apes the extensor brevis digiti quinti is no longer present as an individual muscle, existing only in the form, as so frequent in man, of a slip from the tendon of the per. brevis attached to the metatarsal bone, or the long extensor tendon of the V toe. The accessory peroneal nerve ends in the branch to the peroneus brevis.

Ruge says:—"I have never been able to trace the deep accessory peroneal nerve to the dorsum of the foot in the apes" (compare Hepburn (3)).

The anterior tibial nerve now supplies the whole of the extensor brevis digitorum, which arises on the dorsum of the foot.

Thus we have a fairly coherent sequence. In *Ornithorhynchus* a muscular branch of the peroneal nerve supplies the whole short extensor group, with the exception of the quinti digiti, which gets a special nerve, arising close to it. In *Didelphys* the corresponding nerve supplies the extensor brevis dig. II-IV, a special branch in close connection with it going to the dig. V, while the anterior tibial supplies the extensor brevis hallucis. In the Carnivora the nerve is associated with the cutaneous branch: at its origin from the peroneal trunk it supplies the peroneus brevis and ext. brev. dig. V, and is continued to the foot to supply the ext. brev. dig. IV, now on the dorsum of the foot; it repeats the condition in *Ornithorhynchus*, supplying the joints, but adding the function in certain members of the group of supplying the skin of the 4th and 5th toes. In the lower apes the homologous nerve supplies the peroneus brevis and ext. brev. dig. V, but fails to reach the foot. It has, as a rule, disappeared in anthropoids and man, with the disappearance of the independent ext. brev. dig. V, and the anterior tibial nerve has displaced it on the dorsum of the foot by supplying the whole extensor brevis digitorum.

In the present cases, we have in the human subject a repetition of the ancient supply of the extensor brevis digiti quarti, and a repetition of a long branch of the peroneal nerve going to the dorsum of the foot, to end in the 4th interosseous space, as seen typically in the Carnivora and Rodentia.

I cannot believe, while quite willing to agree with Cunningham, Brooks, Paterson, and others, that the nerve supply to a muscle is not an invariable guide to its homologies,—that we have here to do with a mere shunting of nerve fibres without morphological import, in view of the exact repetition of the course of the nerve found in the Carnivora.

The cases described differ, however, from the condition observed in the lower mammals, in the substitution of the peroneus quartus for the extensor brevis digiti quinti, and they raise anew the question as to the nature of this muscle. Testut (4) regards it as corresponding to a

form of the extensor quinti digiti, and its relations to the deep accessory peroneal nerve strongly support this view. We have a number of anomalous muscles described as arising from the lower part of the fibula.

I. The Peroneus quinti digiti.

Professor Cunningham and Dr Brooks (5) described two instances of an independent peroneus quinti digiti. In one the muscular belly arose from fibula partially blended with the peroneus brevis; in the

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FIG. 4.—Homo.

other, it was attached to the septum between the peroneus brevis and flexor longus hallucis. Professor Macalister (6) and (7) describes it as arising from the lower fourth of the fibula, below the peroneus brevis.

II. The Peroneus quartus in two forms—the peroneo-calcaneus externus and the peroneo-cuboideus. It is present, according to Gruber, in 13 per cent. of cases. In one of my cases it was intimately associated with the peroneus brevis, and arose from the same septum from

which Professor Cunningham describes the peroneus quinti digiti as arising. In the others, it was a mere rudiment, but always attached to the fibula by means of this septum. The conclusion of Testut, that the peroneus quartus and quintus are one and the same muscle seems, therefore, well grounded; and accordingly we may say that the extensor brevis digiti quinti may be represented in man in several forms, and that when the fleshy belly is independent, it is supplied by a nerve homologous with that which supplies the muscle in the lower mammals, viz., "the deep accessory Peroneal nerve" of Ruge.

It may occur, I. (a) As a tendinous slip from the peroneus brevis to the extensor tendon of the little toe, arising from the tendon anywhere between the malleolus and its insertion, or attached sometimes to the base, sometimes to the head of the 5th metatarsal bone. (b) This slip may have developed on it a fusiform muscular belly (8).

II. As an independent muscle, with an independent muscular belly, and a separate tendon inserted into the aponeurosis of the extensor tendon of the 5th toe.

III. In a dismembered condition. The muscular belly is separated from its tendon, and has acquired a new attachment (a) to the calcaneum, (b) to the cuboid, or even (c) to the 5th metatarsal bone, or (d) to the tendon of the flexor longus hallucis; while the muscular belly may, as the peroneus quartus, coexist with the tendinous slip from the peroneus brevis, as in two of the cases which have been the subject of this paper.

Papers referred to.

- (1) RUGE, *Morpholog.-Jahrbuch*, iv. 1878.
- (2) CUNNINGHAM, *Jour. Anat. and Phys.*, vol. xv.
- (3) HEPBURN, *Jour. Anat. and Phys.*, vol. xxvi.
- (4) TESTUT, *Les Anomalies Musculaires chez l'homme*.
- (5) CUNNINGHAM and BROOKS, *Proc. Roy. Irish Acad.*, s. 3, vol. i.
- (6) MACALISTER, *Proc. Roy. Irish Acad.*, vol. x., 1866-67.
- (7) Do. *Trans. Roy. Irish Acad.*, vol. xxv.
- (8) WOOD, *Proc. Roy. Soc.*, vol. xvi.
- (9) POZZI, *Jour de l'Anatomie*, &c., viii., 1872.

Dr BARCLAY SMITH read a paper on certain points in the *Anatomy of the Dorsum of the Hand*. As the result of fifty dissections, he came to the conclusion that the muscular slips to which the term 'extensor brevis digitorum manus' is applied are very much more frequently present than is usually supposed.

The nerve supplies were traced when possible, and these were found to be derived from the deep branch of the ulnar.

From certain relationships to the dorsal interossei muscles, and from the nerve supply, he came to the conclusion that these slips could not be regarded as homologous to the extensor brevis digitorum pedis, although from their disposition they closely simulated it.

He discussed the interpretation of the pseudo-ganglion on the posterior interosseous nerve, and suggested that, if it represents a suppressed nerve supply, it was a cutaneous rather than a muscular distribution which had disappeared.

The paper will be found *in extenso* on page 45 of the *Journal of Anatomy*.

Demonstration Abstract.

Prof. D. J. CUNNINGHAM stated that he had recently made a continuous series of microscopic sections through the upper part of the *Spinal Cord and the entire extent of the Brain of the Orang and Chimpanzee*. Time would only admit of his showing a few of these. All the sections had been stained by the Weigert-Pal method.

Amongst other points he called attention to the following features exhibited by the slides:—

1. By the Weigert-Pal method the more important tracts of nerve fibres were very clearly differentiated from each other. This was particularly so in the case of the fillet, the pyramidal tract, the direct cerebellar tract, &c. These were differentiated not only by the fact that the strands they represent are very compact, but also by the different degrees to which they had taken on the stain.

2. The decussation of the pyramids is complete in both the orang and the chimpanzee.

3. The direct cerebellar tract in the orang is very remarkable. It is of great size, and forms a distinct projection on the surface of the upper part of the cord and on the medulla. It is mapped out with very extraordinary distinctness. The great size of this tract may be associated with the fact that the orang has very special powers of arboreal progression.

4. The great size of the basal ganglia in relation to the extent of the cortex and medullary portion of the cerebrum is very striking.

5. The great size of the anterior commissure in the orang is also a very evident feature in the sections through the anterior part of the cerebrum.

6. The arrangement of the fibres is apparently more simple than in man, and the chimpanzee in this respect resembles the human condition more closely than the orang.

After the meeting, a number of the members of the Society with their guests dined together in the hall of Exeter College, kindly placed at their disposal by the Authorities. The following is a list of the members and guests who were present:—

Prof. G. D. Thane, in the chair; Sir Henry Acland, Prof. A. Thomson, Dr J. S. Billings, Prof. F. Gotch, Dr H. Whitelocke,

Dr Ritchie, Mr Marriott, Mr Hitchings, Mr Pilcher, Prof. Cunningham, Prof. Paterson, Prof. Hughes, Prof. Fawcett, Mr Makins, Mr Lockwood, Mr Openshaw, Dr Birmingham, Dr A. Robinson, Dr Bryce, Dr Kanthack, Mr Targett, Dr Flemming, Dr Barclay Smith, Dr Farmer, Mr Higgins, Dr Curtis, Dr Keith, Dr Elliot Smith, Mr Parsons.

After dinner, the Oxford Medical Club entertained members of the Society at their rooms in St Giles'.

PROCEEDINGS OF THE
ANATOMICAL SOCIETY OF GREAT BRITAIN
AND IRELAND.

NOVEMBER 1896.

THE Annual General Meeting of the Society was held on Wednesday, November 25th, in the Theatre of St George's Hospital Medical School, at 4 P.M. Present—Professor THANE (President) in the chair, twenty members, and nearly 100 visitors.

The minutes of the last meeting were read and confirmed.

The PRESIDENT, in moving the following resolutions, said:—
“Since our last meeting the Society have, in the death of their first President, Sir George Humphry, experienced a loss which will be keenly felt by every member. He was known to all of us: to most he was a friend, to many a dear friend. To Sir George Humphry probably more than to any other individual are due the initiation of this Society and the success which has attended it from the beginning. Another institution for which we are profoundly indebted to Sir George Humphry is the *Journal of Anatomy and Physiology*, of which he was one of the founders, and for several years an active contributor and conductor, and which has been since 1867 the recognised organ of English-speaking anatomists. In the thirty completed volumes of the *Journal* are contained no less than forty-six papers from his pen, all of them interesting, and some of the first importance. Sir George Humphry's anatomical work is in the minds of all of us: his fascinating treatise on the skeleton, in which it is shown how full of life the dead bones are when skilfully handled; his essays on the limbs; his writings on the morphology of the muscular system, which

constitute the backbone of current views on that subject; and his interesting studies of dwarfs and centenarians, with others of the most varied nature. Of Sir George Humphry's labours in other spheres, I will only allude to the Medical School of the University of Cambridge, in which he has raised for himself a monument nobler and more lasting than any work of the sculptor's art. And in conclusion, do we not all, in thinking of him, recall his genial courtesy and kindly humour; how he would encourage the young member with sympathetic appreciation, and with his ready wit enliven any discussion that threatened to be dull? We shall all agree that he was an ideal President.

"On behalf of the Council, I beg to move:—

"(1) That the Anatomical Society desire to express their sincere regret at the death of Sir George Murray Humphry, and their high appreciation of his eminent services to the Society. Sir George Humphry's labours as an active investigator and writer on anatomical subjects, as a founder and editor of the *Journal of Anatomy and Physiology*, as Professor of Anatomy in the University of Cambridge, and as the first President of this Society, have ensured for his name a leading position in the records of Anatomical Science, while the charm of his personal character secured the respect and esteem of all who knew him, as well as the affectionate regard of those who had the good fortune to be more closely associated with him.

"(2) That a copy of the above resolution be forwarded to Lady Humphry."

Prof. Sir WM. TURNER seconded the resolution in the following terms:—

"I wish to be allowed to second the resolutions which have now been moved by the President. My acquaintance with Sir George Humphry extends back for more than thirty years, and during a large part of that time we worked together in various public capacities. We sat for many years on the General Medical Council; we were closely associated with each other in starting the *Journal of Anatomy and Physiology*, and in editing the thirty volumes which have been published up to this time. At his request I co-operated with him, and with you, Mr President, Mr Lockwood, Dr Curnow, Mr Bland Sutton, and others of the anatomical teachers in London, in starting the Anatomical Society, and by your favour I was chosen

as his successor in the presidential chair. In all my relations with Sir George Humphry I experienced invariable kindness and courtesy. I valued his friendship and appreciated his society. I benefited by his clearness of thought and expression, and by the sound judgment which he brought to bear on those subjects in which we were mutually interested. I deplore his removal from us, both as a personal loss and as the withdrawal from our science of one of its greatest ornaments."

The following gentlemen were elected officers for the ensuing year:—*President*—G. D. Thane. *Vice-Presidents*—Johnson Symington, M.D.; R. W. Reid, M.D.; A. H. Young, M.B. *Treasurer*—G. B. Howes. *Secretaries*—F. G. Parsons (England); J. Musgrove, M.D. (Scotland); A. F. Dixon, M.B. (Ireland). *Council*—D. J. Cunningham, M.D., F.R.S.; E. Fawcett, M.B.; Percy Flemming, M.D.; A. Fraser, M.B.; Robert Howden, M.D.; Arthur Keith, M.D.; C. B. Lockwood; A. Macalister, M.D., F.R.S.; J. Yule Mackay, M.D.; G. H. Makins; T. H. Openshaw, M.B., M.S.; A. M. Paterson, M.D.; Arthur Robinson, M.D.; T. W. Shore, M.D.; Barclay Smith, M.D.; J. H. Targett; Arthur Thomson, M.B.; G. R. Turner; Sir Wm. Turner, F.R.S.; Bertram Windle, M.D.

The Treasurer's Report, showing a balance of £69, 19s. 2d., was received and adopted.

In presenting his Annual Report, the HON. TREASURER remarked that during the year there had been five resignations, and that the names of seven persons had been removed from the roll, chiefly in association with the recovery of serious arrears—of which he was happy to say the subscription list was now wholly free. He remarked that the financial feature of the past year had been the small amount received in annual subscriptions—the smallest in the history of the Society: an interesting fact in consideration that for three of the last five years the income from the year's subscriptions fell far behind the expenditure.

Concerning the future, he remarked that the sum of £15, to be paid on the passing for press of the proofs of the Index to vols. xxi. to xxx. of the *Jour. Anat. and Phys.*, the MS. of which is now in the Editor's hands, represented the only liability; and that unless the working expenditure should be inordinate during the current year, that ought to be one of an improved financial position. With the election of the three candidates for membership that afternoon, the

number of persons on the Society's roll would reach 148; and, in anticipation of a more regular response to the demand for subscriptions, and of the national and historical interests which would attach to the events of the year 1896-1897, he was disposed to suggest to the Council the founding of a Jubilee Prize, as a fitting record of the work of the Society, and of the progress of Anatomy during the Victorian era.

The following candidates were elected members;—J. LYNN THOMAS, 28 Charles Street, Cardiff, proposed by A. W. Hughes, G. D. Thane, F. G. Parsons. JAMES CANTLIE, Lecturer on Applied Anatomy at Charing Cross Hospital, proposed by Stanley Boyd, H. Waterhouse, F. G. Parsons. LOUISE APPEL, M.B., B.S., Demonstrator of Anatomy, London School of Medicine for Women, proposed by Stanley Boyd, A. F. Piercy Evans, P. Flemming.

Prof. WARDROP GRIFFITH demonstrated the following specimens:—*Heart with Imperfection of the Septum of the Ventricles, and other anomalies not giving rise to cyanosis during life.* This specimen was from a female child, aged 5 months, who died from causes unconnected with the circulatory system. During life it was noticed that the heart was enlarged and was beating strongly, and a loud systolic bruit was audible over the precordial area. *There was no cyanosis.* The external configuration was not quite natural; the whole heart was large and massive, and the muscle of the ventricular part was very distinctly marked. There was enlargement and prominence of the right auricle, while the left auricle was small and entirely in the back ground. The pulmonary artery was about double the calibre of the aorta; the valves guarding the orifices of each were perfect, and had the usual mutual relationship. The coronary arteries arose normally.

The auricular septum ended below in a free, well-defined, slightly concave margin. It was perforated over the area of the fossa ovalis by many small rounded and oval apertures. The appendix of the right auricle was large and patulous, and had passing across it in a horizontal plane from before backwards a septum dividing its distal part into two compartments, an upper and a lower. The superior and inferior cavæ were natural, but the Eustachian valve, which was small, in being continued on to the auricular septum, embraced in its concavity the opening of the coronary sinus, which was devoid of any trace of Thebesian valve. The interventricular septum was very short, forming an obliquely antero-posterior ridge in the lower part of the ventricular cavity. Traced backwards and upwards it tapered off and seemed to be continuous with the lower and back part of the auricular septum, a flap of auriculo-ventricular valve intervening, to the deep aspect of which there passed from the tapered part of the septum a small triangular fold of fibrous tissue. Traced upwards and

forwards, the septum also tapered off, and ceased just below the junction of the anterior and postero-left aortic segments. Passing back from this situation to the ventricular aspect of the anterior mitral flap was a small thin fold, which was continuous above with the fibrous tissue below the anterior and postero-right aortic segments, and evi-

A B

Sup. Ven

Coron. Sin

Eustachian V.

Fig. I

dently represented, with its free lower margin, that part of the arterial bulb septum with which the ventricular septum should have blended.

The auriculo-ventricular openings were not cut off from one another: there was one large aperture leading from auricular to ventricular part of heart. The auricular septum barely came down flush with

B. 2. 1. 2.

*edge of Aortic bulb
Septum*

Fig. II *Transverse section*

this opening, while the centre of the ventricular septum was one inch below it. Guarding this aperture were valves provided with chordæ tendineæ, which, with some care, one could make out to correspond with the two mitral and the three tricuspid segments.

The great point of clinical interest in this case is the absence of

c

cyanosis during life, with a malformation of the heart of such a kind as might, one would think, have been associated with a free intermixture of the blood returned from the lungs and from the general system. I do not intend to discuss the matter here, however, further than to say that as there was no obstruction to the passage of the blood in the normal direction, the mixture of the two streams may perhaps not have been great, and also that the greater calibre of the pulmonary artery than the aorta would tend to prevent cyanosis.

Heart showing Abnormal Pulmonary Valves, with great dilatation of the trunk and branches of the pulmonary artery.

This specimen, taken from a man who died of cerebral hæmorrhage, weighed 16 oz., and presented well-marked hypertrophy without much dilatation. The foramen ovale was closed. There were some slight degenerative changes in the mitral valve, which however was, I think, functionally perfect. The pulmonary artery (fig. 1) gradu-

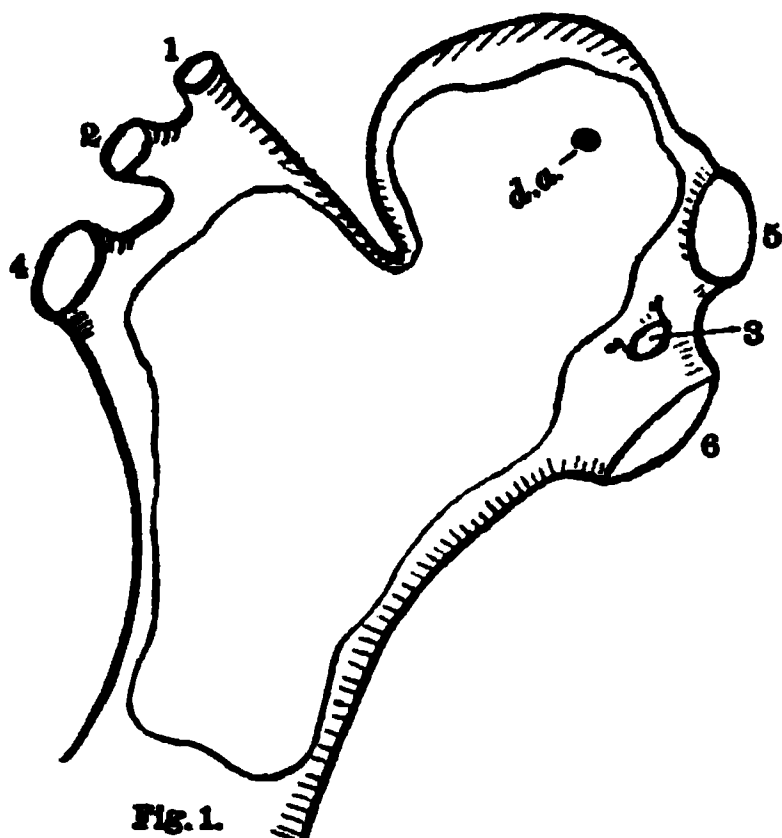


Fig. 1.

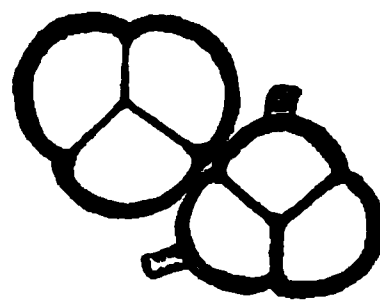


Fig. 2.

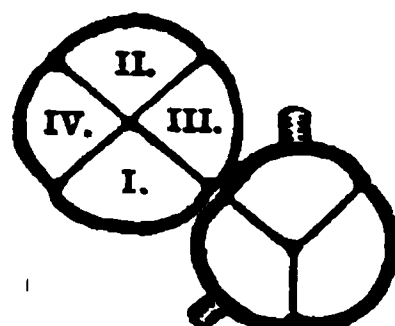


Fig. 3.

ally dilated in a trumpet-like manner from just above its origin, the dilatation involving its two divisions, and some at least of its main branches. The globular dilatation of the left artery would have easily accommodated a golf ball. The walls of the vessel were quite healthy and free from any sign of atheroma, and I do not think there was any lessening of the elasticity of the dilated part as contrasted with the non-dilated. The secondary pulmonary branches, numbered 1-6 in the diagram, varied in size from that of a small pencil to that of one's thumb. The ductus arteriosus was closed.

The pulmonary valve segments were four in number, and practically all of equal size. They were very deep, measuring $\frac{3}{4}$ inch from attached to free margin; and, needlessly large, one would say, for the orifice they had to guard, must have pressed against one another to a greater extent than normally during the arterial recoil. They were thick and strong in texture, and there was no lunule; indeed, the

margin was thicker than the general surface of each flap. The segments were slightly confluent at their commissures, the union between segment I and its neighbours III and IV being a little more extensive than that between segment II and these flaps. There was very little difference in size between the openings into the different sinuses of Valsalva: that marked I was the smallest, and the others followed in the order they are numbered. The presence of four flaps in the pulmonary valve of practically equal size cannot be accounted for on pathological grounds, and a consideration of their position (figs. 2 and 3) would lead to the conclusion that segments II and IV had resulted from a division of the endocardial cushion which normally develops into the antero left pulmonary segment, or, what is practically the same thing, that this cushion had been replaced by two.

Dr ROLLISTON showed the three following specimens:—

I. *Heart, showing a muscular band passing between the two muscoli papillaris of the left ventricle, and capable of acting as a moderator band.*

Arising from the base of the left muscularis papillaris of the left ventricle there is a round muscular band which rises upwards and joins the right musculus papillaris obliquely near its summit; when the heart is relaxed it looks merely like an anastomosing trabecula

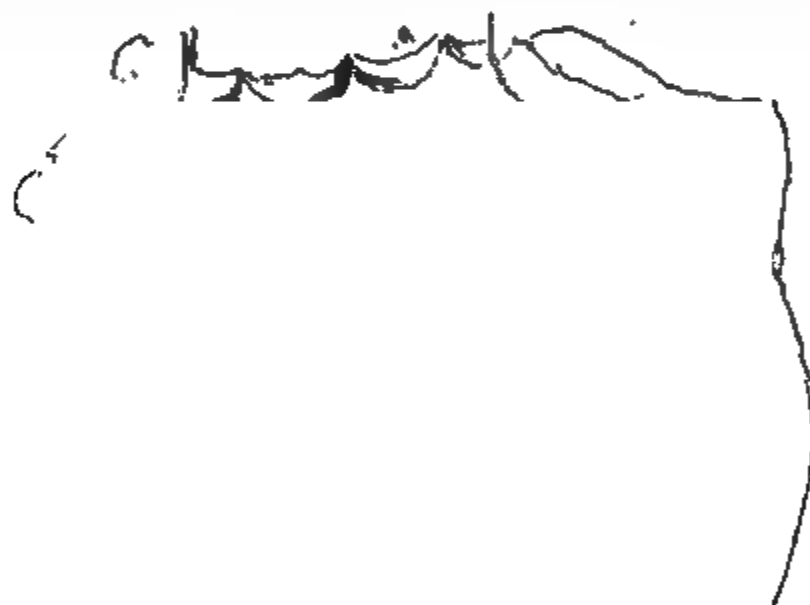


Fig. D.

passing the muscoli papillaris. But when the walls of the heart are drawn apart, this muscular band appears to run transversely from the outer wall of the left ventricle to the right or anterior musculus papillaris (as shown in fig. D). It thus represents a moderator band on the left ventricle, such as have already been described by Sir W. Turner.¹ It also illustrates the way in which a moderator may be

¹ *Journal of Anatomy and Physiology*, vol. xxvii. p. xix. and vol. xxx. p. 568.

evolved from the columnæ carnes of the ventricle, apparently only acting as a moderator band when the ventricle becomes dilated or its walls stretched.

In this specimen it appears probable that the normal position was that first described, viz., lying oblique on the left ventricle, and not running transversely across its cavity; since putting it in the position of a moderator band makes some of its fibres appear to run in an abnormal or twisted manner.

II. *Heart, showing dwarfing of the right or anterior musculus papillaris of the left ventricle, and, as a result, attachment of the anterior cusp of the mitral valve directly to the septum.*

CH. 100

Fig. E.

The inner anterior or larger segment of the mitral valve is attached normally at its left extremity to the chordæ tendinæ of the left or posterior musculus papillaris (A, fig. E), but at its right extremity it arises directly from the septum of the ventricles. This is owing to the absence of any chordæ tendinæ from the right papillary muscle. There is, in fact, hardly any musculus papillaris representing the right or anterior one (B).

The posterior musculus papillaris is seen to be larger than normal, and perhaps has hypertrophied to compensate for the failure of its fellow.

For the drawings which illustrate this and the previous specimen I owe my sincere thanks to Dr G. H. Goldsmith.

III. *Heart, showing aberrant attachment of chordæ tendinæ on the left ventricle.*

There are two isolated and single chordæ tendinæ showing abnormal attachments.

(1) A chorda tendinea, $1\frac{1}{4}$ inches in length, arises from the right musculus papillaris on the left ventricle, and runs up to be attached to the anterior or larger cusp of the mitral valve, quite close to its base of attachment on its ventricular aspect, just below the base of that aortic valve segment which has not a coronary artery arising from the sinus of Valsalva. This aberrant chorda has no attachment to the edges of the mitral valve.

(2) A chorda tendinea, $\frac{3}{4}$ inch in length, arising from the left musculus papillaris, and running to be attached to the endocardium covering the outer wall of the left ventricle.

This chorda has no attachment to the mitral valve segments.

In none of these three hearts was there any evidence of pathological change, and there is no reason to think that the abnormalities described were responsible for any inconvenience during life, or embarrassed the work of the heart.

Professor WARDROP GRIFFITH showed a specimen of *Musculus Supraclavicularis proprius* of Gruber. The muscle was present on

the left side only, and occurred in a male subject. Its origin was from the inner part of the anterior aspect of the clavicle, slightly tendinous, and quite distinct from the sterno-mastoid and pectoralis major. It passed out above the clavicle, and expanding into a tendinous lamina, was inserted partially into the skin and partly into

the fascia over the trapezius, clavicle, and deltoid. Two supra-clavicular twigs, from the inner of which its nerve was derived, passed between it and the clavicle, while the supra-acromial branch passed through its aponeurotic expansion.

Professor GRIFFITH then read a paper on an *Abnormal Muscle of the Hand*, with remarks on the course of the radial artery. The paper will be found *in extenso* on p. 283 of the *Journal of Anat. and Phys.*

The abnormal muscle was the first dorsal interosseous, and the writer draws attention to the frequency of variation in it. The relation of the radial artery to the adductor obliquus is discussed, and

attention directed to the ligament which connects the proximal ends of the first and second metacarpal bones.

Mr ARTHUR KEITH brought before the meeting an Indian *Contor-*

tionist, who could throw his limbs into a great number of abnormal postures. The contortionist was a Panjabi, and belonged to that peculiar ascetic sect of Brahmins known as Yogi. He was believed to be the first of his sect that had visited England. He was forty-five years of age, and for the last forty years, in obedience to the religious tenets of the sect to which he belongs, practised putting his limbs in many peculiar postures that had an interest for

anatomists. The accompanying two blocks, which are here reproduced by permission of the Editor of the *Sketch*, show some of the Yogi's peculiar postures. All his contortions are due to a power of hyper-flexion of the knee, hip, ankle, elbow, shoulder, and wrist joints. He had no power of hyper-extension in those joints. To perform these movements the ligaments of these joints had become elongated to a marked degree, and yet the Yogi could walk and jump with the greatest precision. It was impossible to make a thorough passive examination of the joints, as the muscles surrounding them involuntarily contracted and kept the bones firmly in apposition. In hyper-flexion of the hip-joint the head of the femur made the same peculiar noise as is heard in disarticulation of that joint. The contortions cause the Yogi no pain; and one of his most peculiar postures, which consists in supporting his body on the tips of his fingers with his legs folded over his loins, he undertakes to keep up for five days on end. His bones were quite normal in rigidity and in shape.

The Yogi went through over thirty different postures before the meeting.

Professor THANE pointed out that the condyles of the humerus and the olecranon kept their normal positions in the various postures into which the arms were thrown. He was also of opinion that the crucial ligaments of the knee-joint were quite in a normal condition.

Mr A. F. TREDGOLD read a paper on *Rib Variations in the Primates*, with especial reference to the *number of sternal ribs in man*. The paper is printed *in extenso* on p. 288 of the *Jour. of Anat. and Phys.* The ribs normally found in man are 7 true, 3 false, and 2 floating; but deviations from this arrangement are repeatedly noticed: these are—

1st, An *increase* in the total.

2nd, A *decrease* in the total.

3rd, An alteration in the number of true ribs, or a variation in the attachment of the 8th costal cartilage.

"Is it possible," he asks, "to account for these abnormalities by a study of the rib variations in the lower primates?"

He had obtained particulars of 10 genera,—in all, 380 specimens—made up of 81 monkeys, 52 apes, and 235 men; and care had been taken to only include those specimens which might be considered quite reliable and untampered with. In this series the following facts are noticed:—

1st, That a gradual reduction takes place in the total number of ribs with rise in the animal scale.

2nd, That a coincident and proportional reduction takes place in the number of sternal ribs.

3rd, That the 8th rib tends, from a sternal, to become a costal one.

And that these changes are inter-dependent, and conduce to

4th, A gradual shortening of the thorax from below.

The writer illustrated these facts by means of a diagram and table

(see complete paper), the diagram showing the relation of the 8th costal cartilage, and the number of true and total ribs in Man, Apes, Semnopithecii, Macaci, Cercopithecii, Platyrrhini and Lemnoidæ, and the table giving the *average* arrangement in each class, and thus showing the changes numerically.

From these the series of changes are readily seen: also the gradual reduction of total and true ribs, and of the thorax as a whole, and the tendency of the 8th rib, from a sternal, to become a costal one.

In man there are only occasionally (10 per cent. of cases) 8 true ribs. In apes 30 per cent., and the number of cases steadily increases, until in Cercopithecii there are 100 per cent., an 8th true rib always occurs; and going down still further, we get a constantly increasing proportion of 9, 10, 11, and finally 12 sternal ribs.

With regard to the cause of this, it is probable that the increased variety of movement which takes place in the arms causes a change in the shape of the upper part of the chest from a compression laterally to one from before backwards, and an increase of capacity, and that a compensatory reduction takes place below. Certainly this expansion above and reduction below go hand and hand.

What bearing have these changes upon human abnormalities?

1st, With regard to the variability of the 8th rib.

This has lately attracted considerable attention. An 8th true rib occurs in man in about 10 per cent. of cases, and it has a singular preference: it is more common on the right side, and in the male sex. The writer had been unable to find this preference obtain in either apes or monkeys.

Professor Cunningham considers that it is brought about in man by his being right-handed, but there are several objections to this:—

1st, That in man an 8th true *left* rib is found in a proportion of cases far in excess of left-handed people. In fact, an 8th rib does not occur so much oftener on the right than left side in males, although it does in females.

2nd, The preference is unnoticeable in the apes; and they, especially the orang, are also right-handed.

3rd, This *extension* of an 8th rib to the sternum would necessarily imply that man, or his predecessors, originally possessed but 7 ribs, whereas we have seen that a decided increase takes place in the number of true ribs as we go down the scale.

The change is a distinctly progressive one, and Mr Tredgold believes more probable explanation is this:—

That man's thorax, in common with all the primates, undergoes that gradual shortening from below: that part which is more functionally important is more persistent, that which is less so is more inclined to go first. The ribs, originally protective for dorsal nerve and blood systems, have become so modified in amphibians, birds, and mammals, as to be secondary structures almost solely to the lungs, affording them protection, and being the chief agent in their expansion. The right lung is of greater functional value than the left, weighing 2 oz. more, and the reduction of the 8th rib is conse-

quently less apt to occur on that side. The liver is also an important organ, needing protection, and probably exerts an influence on the persistence of the 8th right rib to the sternum.

With regard to the variations in total number of ribs, the same takes place amongst monkeys and apes, and the explanation is probably twofold:—

1st, That additional ribs are true to the persistence of a former condition. Parker states that in the embryo of man cervical and lumbar ribs are actually laid down, but subsequently disappear.

2nd, That decrease, which nearly always occurs below,—and in man there are numerous instances of rudimentary 12th ribs,—is but a part of that steady progressive decrease which has been seen to run right through the order. Possibly the anatomist of the future will describe the normal number of ribs in man as 11.

PROCEEDINGS OF THE
ANATOMICAL SOCIETY OF GREAT BRITAIN
AND IRELAND.

MARCH, 1897.

AN Ordinary Meeting of the Society was held on Friday, March 12th, at 4 P.M., in the Anatomical Theatre of University College,—Professor THANE in the chair. Twenty-five members and sixteen visitors were present.

Letters acknowledging the resolution passed at the last meeting of the Society from Lady Humphry and A. P. Humphry, Esq., were read.

The following gentlemen were elected members of the Society:—
T. E. GORDON, M.B., Demonstrator of Anatomy, Trinity College, Dublin, proposed by D. J. Cunningham, A. F. Dixon, F. G. Parsons.
E. H. TAYLOR, M.D., Examiner in Anatomy, University of Dublin, proposed by D. J. Cunningham, A. F. Dixon, F. G. Parsons.
RAYMOND JOHNSON, M.B., B.S., F.R.C.S., Assistant Surgeon to University College Hospital, proposed by G. D. Thane, T. W. P. Lawrence, P. Flemming.
N. H. ALCOCK, B.A., M.D., Demonstrator of Anatomy, The Owens College, Manchester, proposed by A. H. Young, A. Robinson, D. J. Cunningham.
A. W. SHEEN, M.D., M.S., F.R.C.S., Demonstrator of Anatomy, University College of S. Wales, Cardiff, proposed by A. W. Hughes, E. T. Hamilton, F. G. Parsons.
G. BROOKSBANK JAMES, F.R.C.S., Demonstrator of Anatomy, Westminster Hospital, proposed by J. Black, W. H. Marett Tims, F. G. Parsons.
P. FURNIVALL, F.R.C.S., J. S. SLOANE, M.B., B.Sc., F.R.C.S., W. E. MILES, F.R.C.S., Assistant Demonstrators of Anatomy, St

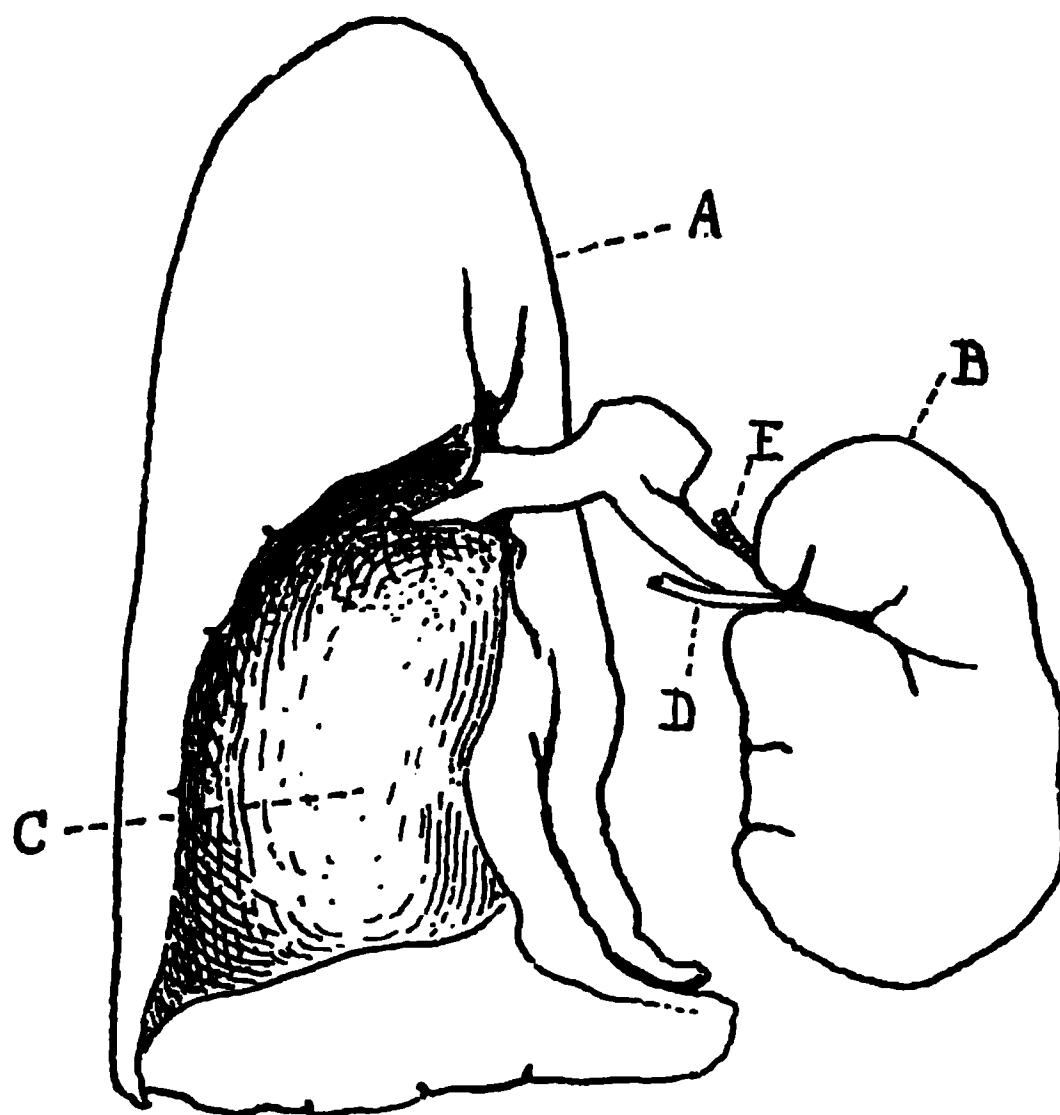
Bartholomew's Hospital, proposed by H. J. Waring, R. C. Bailey, G. B. Howes. R. J. GLADSTONE, M.D., F.R.C.S., 1 Gloucester Gate, Regent's Park, N.W., proposed by J. Bland Sutton, A. Robinson, G. D. Thane. G. F. BARNARDO, M.B., C.M., proposed by A. Keith, P. Flemming, F. G. Parsons.

Mr BLACK showed an *Axis with a Median Cleft of the Neural Arch*, due to want of fusion. The two halves of the neural spine were about 2 mm. apart, and parallel with one another, and from the appearance of their opposed surfaces these must have been free and unconnected by cartilage. A small ossicle, however, connected with the right half of the neural arch by a suture, partly obliterated, had reduced the gap to a mere fissure in the immediate vicinity of the neural foramen.

A *First Thoracic Vertebra* was also shown, presenting a cleft passing obliquely between the superior and inferior articular processes of the right half of the neural arch, and a *Fifth Lumbar* presenting the same feature. This condition Sir William Turner found in 5 out of 31 specimens of fifth lumbar vertebræ of the skeletons referred to in the Challenger Report, part xlvii., 1886; and Bland Sutton states in *Morris' Anatomy*, it probably exists in 5 per cent. of all fifth lumbar vertebræ. Professor Thane had a specimen of a fourth lumbar vertebra, showing the same appearance; and in *Quain's Anatomy* he states that MM. Rambaud and Renault say there are always two ossific nuclei for each half of the neural arch of vertebræ. Although it is of rare occurrence to find the cleft in other than the fifth lumbar, the fact of its occurrence in vertebræ so widely separated as the first thoracic and the last of the movable vertebræ does certainly seem to lend support to such a double origin.

Mr LAWRENCE exhibited a *Lung with Abnormal Lobe*. This specimen (fig. A, view of the posterior border, the smaller lobe being displaced to the right) is a left lung of the following dimensions—height, 8 inches; width, $5\frac{1}{4}$ inches; thickness, $1\frac{3}{4}$ inch. Its weight is $15\frac{1}{4}$ ounces. There is no record as to whether it was taken from an adult. Two distinct lobes are present: the larger one (A) constitutes the greater part of the lung; the smaller (B) fits into a depression (C) in the lower half of the posterior border of the larger lobe. The dimensions of the smaller lobe are—length, 4 inches; width, $2\frac{1}{4}$ inches; thickness, $1\frac{1}{4}$ inch. From the lower part of the anterior border of the larger lobe a fissure starts and passes upwards

round the outer surface of the lung; on the mesial surface the same fissure runs up towards the hilum; the surfaces bounding the fissure were intimately united by adhesions, which were carefully divided and the fissure traced upwards about half the height of the lung, at which level it ceased. The bronchus divides into two branches, the upper one going to the main lobe, the lower one, almost equal in diameter to the upper, to the smaller lobe. The arrangement of the arteries, veins, and bronchial tubes at the hilum is that normal to the left lung. A sulcus in the outer surface of the smaller lobe lodges the vein (D) of the lobe. One of the branches (E) of the pulmonary artery enters the lobe with the bronchial tube and



superiorly to the latter; and another branch or offset of the last-named branch passes superficially down the inner surface of the lobe close to the anterior border, almost reaching the lower end of the lobe, and distributing branches to the organ in its course.

From the situation of the smaller lobe, the large size of the bronchial tube going to it, and the absence of any complete fissure corresponding to the normal fissure of the left lung, it is concluded that the smaller lobe is an imperfectly formed lower lobe, and not a supernumerary lobe.

The specimen was taken from a patient under Dr Bradford.

Dr PERCY FLEMMING showed three specimens of *Abnormal Muscles* that had been found during the present term in the dissecting-room of University College.

A Rectus Femoris with three Heads: the third head, more slender than the others, arose from the upper part of the notch between the anterior iliac spines. The abnormality seems a rare one; it is noted by Macalister and Knott, and Testut merely refers to those cases.

Peroneo-calcaneus internus: the muscles arose from the posterior surface of the fibula for the lower fourth of its extent, below and external to the *flex. long. hall.*, passed beneath the internal annular ligament with the tendon of the latter muscle, to be inserted into the inner surface of the os calcis just in front of the sustentaculum tali, blending with the fascia covering the inner surface of the *flex. accessorius*. At its origin, the muscle could not be distinctly separated from the *flex. long. hall.* for its whole thickness.

A good specimen of this muscle was exhibited before the Society by Professor Thane at the May meeting 1891; and references to other cases, with a figure of the specimen, will be found in the *Proceedings* for that date.

Levator claviculæ. The specimen was found on the right side of a male subject. The muscle arose mainly from the posterior tubercle of the transverse process of the axis, and in addition had a slender slip of origin from the lateral mass of the atlas blended with the tendons of the scalenus medius and levator anguli scapulæ, the main tendon being anterior to the latter muscle over the axis. The muscle was inserted into the posterior surface of the clavicle immediately internal to the conoid tubercle. Its nerve came from the third conical (anterior primary division). There was a well marked cleido-occipital slip on the same side, but not on the left. The clavicle was rather above the average size, measuring 15.5 cm.

The *Levator claviculæ* muscle was first definitely described in man by Wood in *Proc. Roy. Soc.*, 1864, and was referred to by him in subsequent papers in the *Proc. Roy. Soc.*, 1865 and 1867. Its morphology is discussed (with notes of earlier cases) in a paper by Wood in the *Phil. Trans.*, 1869 (vol. 160). A *résumé* of this paper is given in the *Revue d'Anthropologie*, 1888, p. 432.

As regards frequency, Wood's cases give an average of about 3 per cent.; Macalister's, an average of 1 in 60.

The muscle has also been seen coming from the anterior tubercles of the vertebræ (*Journal of Anatomy and Physiology*, 1880, p. 512).

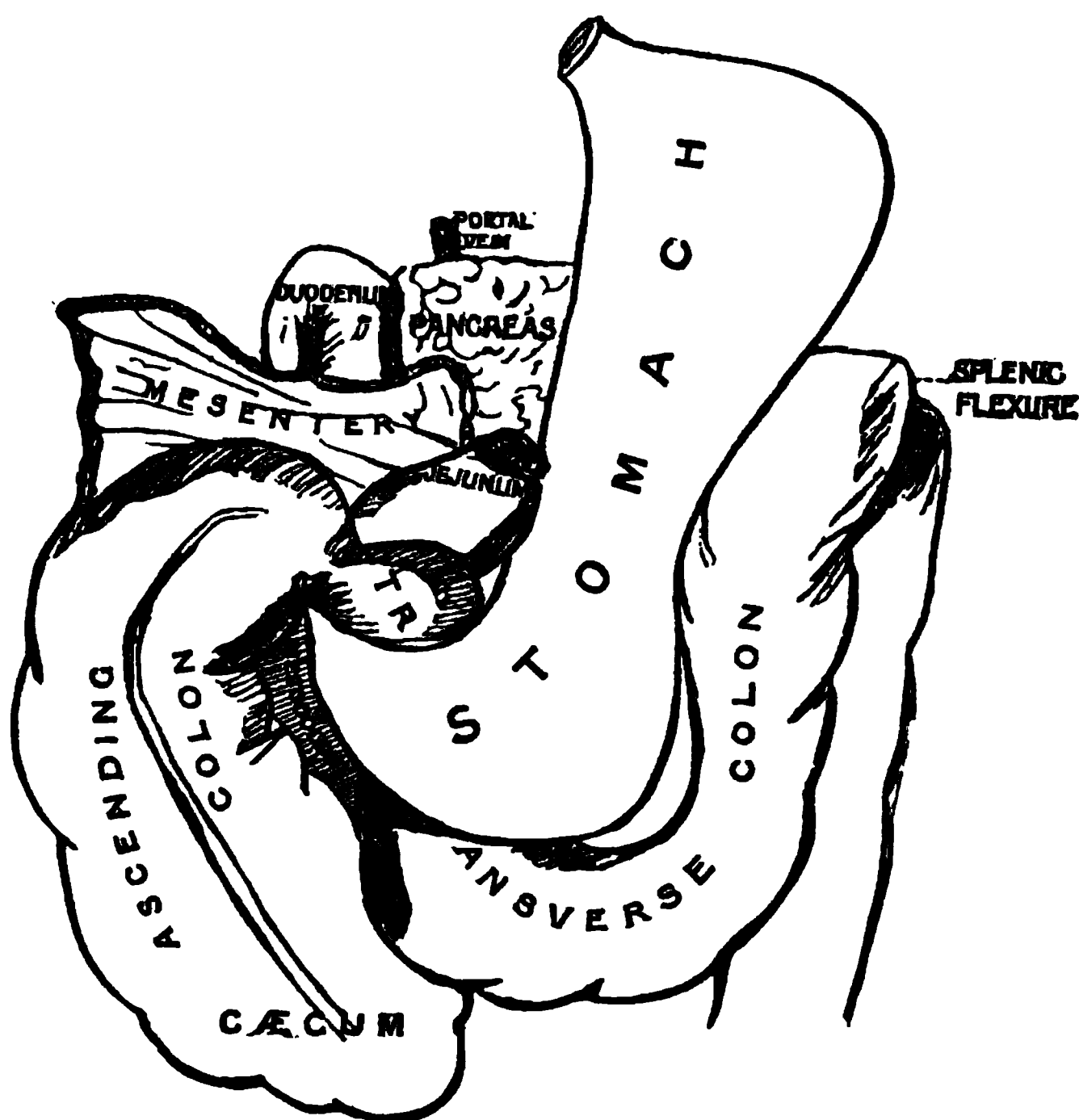
Huxley, Wood, and most authors agree that the muscle is normally present (with a clavicular insertion) in the chimpanzee, orang, gibbon, and gorilla.

Prof. E. FAWCETT showed drawings of two cases of *Levator claviculæ*, as well as a leg with a *Peroneo-calcaneus internus*, a *long accessorius*, and an anterior tibial artery coming off at the upper border of the popliteus and passing in front of that muscle.

Mrs FLEMMING showed a specimen of *malposition of the Colon*. The specimen is from a case of intestinal obstruction which occurred

in a patient under the care of Mrs Boyd, M.D., at the "New Hospital for Women."

The cæcum and ascending colon are much dilated. The free lower end of the cæcum was in the pelvis; the ascending colon occupied its normal position on the right side of the abdomen, and had a distinct mesocolon. From the hepatic flexure the transverse colon passes downwards behind the pyloric end of the stomach, and emerges at its lower border, then follows the greater curvature; but owing to the elongation and downward displacement of the stomach it has to



ascend vertically to reach the splenic flexure, which is at its normal situation. There are adhesions between the descending colon and the ascending part of the transverse colon. The stomach, of hour-glass shape, is dragged downwards. The pyloric wall and the first part of duodenum ascend almost vertically behind the transverse colon and mesentery to the gall-bladder, to which this part of the duodenum is adherent. A very sharp turn then occurs as the second part of duodenum descends to the right of the pancreas, this part and the remainder of the duodenum having normal relations to that organ.

The duodeno-jejunal flexure takes place in the angle between the

transverse colon and the lesser curvature of the stomach: thus the mesentery appears above the right end of the transverse colon, and in front of the junction of stomach and duodenum.

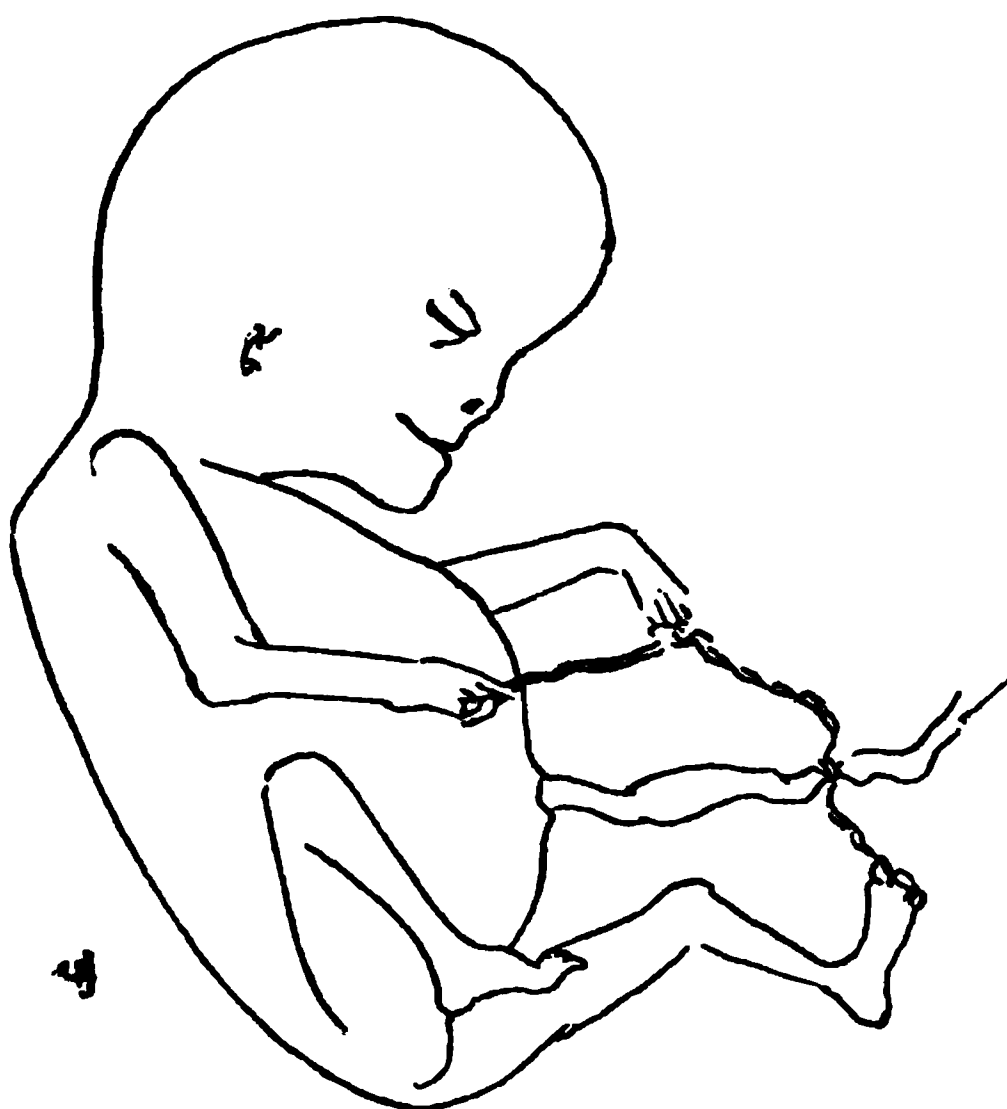
In addition to the main malformation, a portion of the mesentery and small intestine attached (last 10 feet) had, with the cæcum and ascending colon, made a complete twist from left to right, thus producing intestinal obstruction which caused death. The portion of mesentery that was involved in this twist is much thickened, and at the point at which the colon was twisted it is contracted.

Mr CHEATLE showed several specimens of the so-called *Mastoid Antrum*, and said that when it is remembered that most of the serious intracranial complications of chronic middle-ear suppuration, and occasionally of the acute variety, have their starting-point from it (a sort of aural cess-pit, so to speak), no apology was necessary for bringing it under thorough discussion; and he ventured to state that, for its size, it has been the means of destroying more lives than any other cavity in the body. He asked the meeting, (1) Why it should not be described as part of the middle ear, and not part of the mastoid region? It is laid down in foetal life as part of the middle ear, lined with the same M.M., and is constant. Under the present artificial division of the petro-mastoid its description has to be made with the mastoid portion. (2) Why should not this artificial division of the petro-mastoid be done away with, or altered for purposes of description? It cuts off a part of the middle ear, necessitating its description with entirely different parts. Again, if it ought to be described as part of the middle ear, its name is wrong and misleading: tympanic, in the place of mastoid, would be correct. The mastoid process does not even begin to make its appearance until the end of the first year, below the antrum, when its presence becomes necessary for the attachment of powerful muscles, the mastoid cells which form still later serving the purpose of lightening the bone; the cells communicate sometimes with the antrum, but certainly not invariably, the communication being, so to speak, accidental. In the specimens at birth the part of the squamous portion which forms the outer wall of the cavity is invariably cellular: these cells increase in thickness somewhat as life goes on. They have been described as mastoid, but on careful examination the outline of the original finer antral cells can generally be seen, in some more distinct than others, their direction being inwards, while the cells which form outside them are coarser and have no definite direction.

Mr Cheatle then drew attention to a small tubercle which is sometimes present in children behind and above the external meatus. Perforation through this tubercle always leads into the apex or lower part of the antrum. Several of the specimens were so perforated, and some showed this tubercle.

Dr E. BARCLAY SMITH exhibited a foetus of about 13 weeks, presenting a *peculiar condition of the Digits*. Those of the right upper

limb were linked to those of the left upper limb by a short string-like band; while from the digits of the left upper limb a similar but longer band, apparently continuous with the former, passed to the digits of the left lower limb, not directly, however, as between the two it appeared to be tightly tied round the umbilical cord. The umbilical cord at this spot was involved by an annular constriction, and the flow of blood in the umbilical vessels had evidently been hindered by the compressing influence of the surrounding band, which was thereby responsible for the abortion.



Unfortunately there was no opportunity of studying the disposition of the membranes, as the foetus was sent with the cord severed and the placenta and membranes removed.

Undoubtedly the band was amniotic in origin, but it is difficult to conceive how an amniotic band could have attained such a remarkable disposition to the limbs and cord; and further, what revolution the foetus could have undergone relatively to the amniotic sac, in order to account for the production of a spirally twisted band,—a twisting which, for the sake of clearness, has been exaggerated in the diagram, but which is sufficiently obvious when the band is examined with a lens.

Dr T. W. P. LAWRENCE read a paper on an *ill-developed Kidney and Ureter*, the latter passing behind the iliac vessels. The paper will be printed *in extenso* in the *Journal of Anatomy*, July, 1897.

Dr T. H. BRYCE read some "Notes on the Myology of a Negro," which will be published in the *Journal*, July, 1897.

Dr R. J. GLADSTONE read the notes of a case of *Additional Presacral Vertebra*. The paper will be printed in the *Journal*, July, 1897.

Dr G. F. BARNARDO read the notes of a *Case of pure Ectopia cordis*. This also will be published in the *Journal of Anatomy*, July, 1897.

ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

JUNE 1897.

THE Summer Meeting of the Anatomical Society was held in Dublin on the 9th, 10th, and 11th days of June. The use of the Anatomy School in Trinity College was granted to the Society for this purpose.

PROGRAMME

WEDNESDAY.

Reception at 9 o'clock in the evening, at 43 Fitzwilliam Place.

THURSDAY, 10TH JUNE, FORENOON MEETING, 10 A.M.

Election of New Members.

SPECIMENS.

THOMAS H. BRYCE, M.A., M.D. :

A pair of negro Femora, the left of which showed a remarkable development of the popliteal surface.

Professor W. SPALTEHOLTZ (Leipzig) :

Stereoscopical photographs illustrating the distribution of the Arteries in the Human Skin.

Professor H. LEBOUcq (Ghent) :

The ossification of the Terminal Phalanges of the Fingers in relation with hyperphalangy.

SPECIMENS—*continued.*

Mr HAROLD J. STILES :

X-Ray photographs of mercurial injections of the Arteries of the Limbs and Kidneys, and of the Air-tubes in a case of pneumonia.

Professor A. BIRMINGHAM :

Models and specimens illustrating the topographical anatomy of certain of the Abdominal Viscera.

PAPERS.

Dr OTIS (Boston, U.S.A.) :

Some points in the structure of the Rectum.

Professor A. MACALISTER, F.R.S. :

A study of Australian Brains.

JAMES CANTLIE, M.A., M.B. :

On the position of the Gall-bladder.

Professor R. HOWDEN, M.B. :

Note on a case of marked distension of the Colon.

Professor REDFERN, M.D. :

Observations on the development and nutrition of Bone and Cartilage, and on the relations of connective tissues to each other in health and disease.

Professor B. C. WINDLE and F. G. PARSONS, F.R.C.S. :

Note on some points in the Nomenclature of Comparative Myology. See p. 522 of the July number of the *Journal of Anatomy and Physiology*.

THURSDAY, 10TH JUNE, AFTERNOON MEETING, 2.30 P.M.

PAPERS AND LANTERN DEMONSTRATIONS.

Professor W. ANDERSON :

The peritoneal relations of the Sigmoid Flexure of the Colon.

Professor DISSE (Marburg) :

The development of the Olfactory Nerve in Birds.

Professor W. SPALTENHOLTZ (Leipzig) :

Reticulated Tissue : its relation to the cells, and its arrangement in different organs.

Professor A. F. DIXON, M.B. :

Some points in the development of the Eye-muscle Nerves in mammals.

PAPERS AND LANTERN DEMONSTRATIONS—*continued*.

Professor D. J. CUNNINGHAM, F.R.S. :

- (1) The development of the Fissure of Rolando, and the relation which this presents to the growth of the functional areas of the Cortex ; and
- (2) The development of the Calcarine Fissure (lantern demonstration). See p. 586 of the July number of the *Journal of Anatomy and Physiology*.

Dr KAESTNER (Leipzig) :

Some specimens and photographs of Malformed Chick Embryos.

THURSDAY EVENING.

Dinner given by the President of the Royal Academy of Medicine in Ireland, in the College of Physicians, Kildare Street, at 7.45 P.M.

FRIDAY, 11TH JUNE, FORENOON MEETING, 11 A.M.

SPECIMENS.

Professor KARL V. BARDELEBEN (Jena) and Dr FROHSE (Berlin) :

Specimens illustrating the finer ramifications of Nerve-filaments supplying Muscle.

C. J. PATTEN, M.B. :

- (1) Two curious modifications of the Lower Jaw.
- (2) Cervical Vertebra in which the Laminæ have not fused.

Professor D. J. CUNNINGHAM, F.R.S. :

Models and specimens illustrating the form, position, and relations of the Kidneys.

PAPERS AND LANTERN DEMONSTRATIONS.

Professor WALDEYER (Berlin) :

The topographical anatomy of the outer wall of the Pelvis with reference to the position of the Ovary.

G. ELLIOT SMITH, M.D., C.M. :

Observations on the morphology of the Fornix and margin of the Cerebral Cortex.

Dr C. DE BRUYNE (Ghent) :

Adaptation fonctionelle de la phagocytose.

PAPERS AND LANTERN DEMONSTRATIONS—*continued*.

Professor B. C. WINDLE, M.D., Sc.D. :

Priestley Smith's Formol Method of mounting specimens of the Eye (taken as read).

Professor R. HOWDEN, M.B. :

Note on a case of Bifid Scrotum (taken as read).

W. BOOTH PEARSALL, F.R.C.S.I. :

On the linear determination of the human Toothform (taken as read).

WILLIAM S. HAUGHTON, M.B. :

Some application of X-Ray photography to anatomical investigation (taken as read).

Professor D. J. CUNNINGHAM, F.R.S. :

Note on the Cape Hunting Dogs (*Lycaon pictus*) in the Gardens of the Royal Zoological Society of Ireland (taken as read).

Professor D. J. CUNNINGHAM, F.R.S. :

Lantern Demonstration of the deep connections of certain of the Cranial Nerves (fourth, sixth, and seventh) in the Orang and the Chimpanzee (taken as read).

E. H. TAYLOR, M.D., F.R.C.S.:

Demonstration of the Applied Anatomy of the Rectum (taken as given).

FRIDAY AFTERNOON, 4 P.M.

Address by Professor WILHELM HIS on the "Development of the Brain, and the Nerves in connection with it."

This lecture was delivered in the Theatre of the Royal Dublin Society, Kildare Street, under the auspices of the Royal Academy of Medicine.

On Friday evening the Members of the Society dined with the Senior Fellows of Trinity College in their Hall.

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ANATOMY AND PHYSIOLOGY
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VOLS. XXI.-XXX.—1887-1896.

NEW SERIES, VOLS. I.-X.

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1897.

PREFATORY NOTE.

THIS Index to Vols. XXI.–XXX. of the *Journal of Anatomy and Physiology* has been compiled, under the direction of the Anatomical Society of Great Britain and Ireland, by Mr A. W. Kappel, by whom the Index to Vols. I. to XX., issued with Vol. XXVIII., had also been prepared. The Index appears in Vol. XXXI. of the Journal. The Editors desire to acknowledge their indebtedness to the Society, and to express their thanks for the handsome contribution from its funds towards this object. It should be explained that the Roman numerals mark the Volume and the Arabic numerals the page; but when the Roman numeral is preceded by the letter p., the page of the *Proceedings of the Anatomical Society* in the volume is referred to.

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